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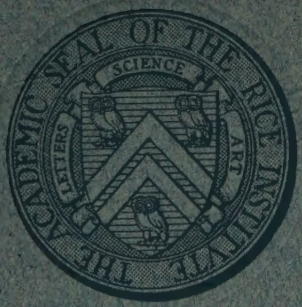

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A university of liberal and technical learning founded by William Marsh Rice in the City of Houston, Texas, and dedicated by him to the advancement of Letters, Science, and Art

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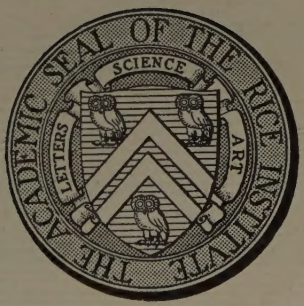

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THE OUTLOOK IN BIOLOGY[1]

I

PURE BIOLOGY

BIOLOGY is the most complex of the sciences, as it is the science of most immediate and direct importance. To the huge complexity of its physical and chemical basis is superadded the complexity of mind, and the whole problem of the relation between the two sides of reality, the material and the mental. And as knowledge of principle grows and becomes translated into practice, it will mould not the environment only, but life and man themselves. With such difficulty of subject-matter and such unavoidable inertia as regards application, there is little wonder that biology has lagged in her advance behind her simpler sisters. Natural science in its latest and its only continuous phase is a growth of a few centuries only. Astronomy, mechanics, physics and chemistry inevitably claimed her early energies. Biology in any modern sense of the term only saw the light in the seventeenth century, and did not begin its first coördinated attack on its subject-matter until the eighteenth. Even so, advance then, and for long afterwards, was chiefly in the methods of classifying organisms, rather than in discovery as to what organisms were

[1] A course of three lectures delivered in the Physics Amphitheatre of the Rice Institute, September 29 and 30, and October 1, 1924, by Julian S. Huxley, Fellow of New College and Senior Demonstrator in Zoölogy, Oxford University, sometime Assistant Professor of Biology at the Rice Institute.

or how they worked. The rise of physiology came in the nineteenth century; and only in our own times is there being effected the reconciliation between the physiologist and the zoölogist by which alone a true biology can live. Let us not be surprised, then, to find that biology must still admit ignorance on many fundamental matters of principle, in a way which the modern physicist finds it difficult to grasp: physics and chemistry must go back to before the time of Faraday and Mendeléeff, in the early middle of the last century, to find a parallel to the biological situation of to-day.

On the other hand, that parallel is full of hope. The first half of the nineteenth century inaugurated the heroic age of chemistry and physics, an age which has not yet closed. We are now I think clearly still living in the early beginnings of biology's heroic age, when generalization upon generalization is being accumulated in all the different fields of the science so fast that they cannot yet be properly correlated.

Knowledge is indeed increasing at a fabulous rate: the committee which is endeavoring to bring into existence a single abstracting journal for the whole field of biology has let us know that each year the number of separate contributions to knowledge in this field is in the neighborhood of forty thousand (and hopes to give us abstracts of the lot within the space of a modest six thousand-page annual volume)!

Knowledge is increasing fast, and, in spite of the vast realms of ignorance beyond, is already considerable. How considerable may best be seen by comparing our present knowledge with our past lack of it.

The history of biology has been in the main a history of separate and often unconnected "drives", each aiming

at the conquest of one particular sector of the field. It is really only within the last twenty years that it has been possible to envisage a single science of biology whose unity shall be practical and organic, as in modern physics, instead of theoretical or remote.

The first drive was that of the early anatomists who, despite prohibition and public sentiment, were resolved to chart the interior of the human body. The knowledge thus gained was the direct progenitor of early physiology, the facts of structure revealing of themselves the elements of function, a process most classically illustrated by Harvey's discovery of the circulation of the blood in the seventeenth century.

Meanwhile a wholly unconnected line of advance had been made by what we may call the collecting spirit. In every age the strange and the novel attract interest, in every society endowed with leisure and intelligence there are men with the boyish passion for making collections raised to a level at which it is active throughout life. Thus arise "cabinets of rarities", and thus the cabinets are converted into museums and comprehensive collections. With the growth of collections arises the need of arrangement; and this arrangement needs must be in the long run not merely a physical convenience, a simple docketing and pigeon-holing, but the outcome of an intellectual process, based upon a perception of similarities and differences, of relationships.

Thus collections beget classifications. Men like Tradescant and Ashmole paved the way and accumulated the materials; others like Ray, following in the footsteps of Gesner, began to codify; until finally in the eighteenth century the genius of Linnæus perceived both the vastness of the task and the necessity for some orderly

and embracing system; and so the modern idea of classification dawned for biology. Buffon, Lamarck, Cuvier, the St. Hilaires continued the drive, de Candolle, von Baer, too, and Owen later. Goethe and Oken speculated platonically upon classification's basis; and Huxley, Hooker, Müller and a score of others were busily engaged in perfecting the scheme when the genius of Darwin provided, in the shape of the evolutionary idea, the key to its meaning. A natural classification could and must exist; and its bases were descent and relationship. Classification must always aim at providing a family tree of the whole world of living beings.

In addition, the seventeenth century saw the opening of another field: the microscope revealed a new world—a new complexity of parts in the larger organisms, a new and immense host of small organisms previously unsuspected.

The late seventeenth and the eighteenth centuries witnessed the first attempt at a unified biology in the sense of an attempt to discover the general properties of life. While the collectors and classifiers, their work epitomized for us in Linnæus' *Systema Naturæ*, were revealing on the one hand the variety and number of the forms which life could assume, and on the other the orderliness of their grouping and the fact that a few general plans underlie the diversity; while the medical physiologists were pushing forward with their analysis of the way in which man and the higher animals work;—a group of brilliant men in various countries were laying the foundations of what we now call general biology (though the word itself was as yet unborn) by studying the processes and possibilities of life in the most widely separated forms and under the most varied aspects.

Harvey, not merely discoverer of the circulation, but

with his dictum *omne vivum ex ovo* and his investigations into reproduction; Leeuwenhoek, the first man to see the spermatozoon, or male element in fertilization; Trembley, with his discovery of regeneration in animals, a discovery quickly taken up and amplified in splendid fashion by Bonnet, Spallanzani and Réaumur; Redi, the first to deal a blow at the superstition of spontaneous generation; Spallanzani again, that versatile Abbé, who succeeded in effecting artificial impregnation in cats and dogs, reformed our whole notions of digestion, and also concerned himself with spontaneous generation; Wolff, the first to establish, if not to describe, the true course of development in higher animals and so to lay the foundations of embryology; Bonnet, and his discovery of parthenogenesis—these men and these ideas show what a ferment of activity was generated in the biological science of that day by a mere handful of workers.

But the time was not yet ripe for biology's unification. The mass of detail revealed on every side was too vast, and yet the known facts and principles—and let us hasten to add, the workers—too few. In many fields, decades of straightforward collection and observation were necessary before a generalization could be anything but provisional, while in others new methods and new ideas were needed before there could be fruition. The science had to split up into sub-sciences once more.

The sub-sciences were largely determined as to their size and field by the exigencies of teaching. The teaching of medical students became ever more and more specialized, and soon became organized into two separate departments, that of anatomy and that of physiology. In the early days the courses in physiology were so meagre in content compared with those of anatomy that the study of

minute anatomy or histology was made over to the physiologists as a makeweight—an anomalous situation which still survives in most universities. As anatomy became more and more specialized, so it shed more and more of its comparative nature and became more exclusively human, (though on the whole regrettably less and less humanist!). In certain quarters it has earned of late years the nickname of 'anthropotomy' and the unenviable reputation of the science without principles. There are to-day, however, signs of a revival in this field. Anatomy in its beginnings was the parent of physiology; to-day it is being regenerated by its offspring.

Zoölogy as a teaching subject became largely restricted to comparative morphology and comparative embryology. Of late years, experiment has come to play a greater part in it, chiefly in regard to regeneration and embryonic development. But the connection (doubtless necessary) of animal physiology with medicine, together with the vast range of subjects comprised within the animal field, has in general brought about a disastrous cleavage in animal biology between the study of structure and the study of function. There is, after all, some truth in the bitter saying of Radl, in his *History of Biological Theory,* with regard to post-Darwinian zoölogy—that it was so busy comparing one thing with another that it did not try to find out what any of them really *were!*

Botany, with less appalling range of subject-matter, has been able to keep man and wife together—to prevent the dissolution of the bond between structure and function. On the other hand, botany and zoölogy have not been as close coöperators as could have been desired. This again springs from historic causes—namely, that in both subjects as actually taught and separately recognized, the point of

view was at first an extensive one—the diversity of types and their comparison. It could not be the intensive and more fundamental study of principles common to both botany and zoölogy, for of many of these principles, not even the first adumbration had yet been discovered.

Of late years, with the multiplication of knowledge, an inevitable multiplication of independent scientific departments has occurred. Pathology has split off from physiology and anatomy and allied herself with bacteriology. Chemical physiology has had herself rebaptized as biochemistry, prior to leaving the parental roof and setting up house on her own. Plant breeding and animal breeding have joined hands as genetics. And there are here and there in existence departments of biometry, of biophysics, of vital statistics, of economic entomology, of plant pathology, of biological survey, of race biology, of experimental zoölogy, of animal behavior.

The problem for education is a difficult one. How far are the old lines of cleavage to be dropped, and new ones, based on the discovery of general underlying biological principles, to be adopted? Luckily, however, that is not our problem to-day. We are here only concerned with the development of the different lines of biology to the point at which unification of principles has become possible; and we must turn back to the actual course of biological history in the nineteenth century.

First, then, on the side of comparative biology. The main outlines of a rational classification were laid down by 1850; but no one had discovered *why* the classificaton was rational. Kant had said, half a century back, that biology was waiting for its Newton; and Charles Darwin arose to fulfil that rôle. By establishing the theory of descent with modification on a firm basis he showed that the resemblances

and the differences between organisms were explicable, not on the essentially mystical views of the *Naturphilosophen,* as so many expressions of a few archetypal ideas laid up in the mind of Divinity, but on the degree of actual blood-relationship between the organisms.

We moderns take the theory of evolution so much for granted that we sometimes fail to realize the extent of our debt to Darwin. It was he who first showed that a truly scientific basis for a unified science of biology was possible at all. But this was not all—he did more than any other single man since Newton to help inaugurate what we may call the scientific revolution in thought. I shall, perhaps, not be straying too far from my subject if I digress for a few moments to amplify this aspect of his achievement; for, as a matter of fact, a unified science of biology is of necessity correlated with and a preface to the unitary system of thought towards which, and away from dualism, the world is tending.

If we look back a hundred years or thereabout, what do we find in Europe? We find the nations dominated by one or other of a set of ideas which are now fast disappearing, or at any rate are becoming relegated to subordinate positions.

Go back, then, a hundred years. In some places, the Divine Right of Kings and Emperors is still accepted. In others, society is holding by watchwords like Liberty, Equality and Fraternity—ideal aspirations rather than practicable rules of life, often, like Equality, based in and leading to error. Where the traditional and unreasoned beliefs of centuries have broken down, men are endeavoring to put something new in their place; but the new principles lack basis, and are often too plainly abstractions of the inner consciousness rather than practicable embodi-

ments of experience. Abstractions are the order of the day. Economic abstractions in Great Britain paved the way for many of the mistakes following the Industrial Revolution: untrue hypotheses about Equality had helped France to lose her real liberty once more: the utilitarian abstractions of the Benthamites attracted by their logic but did not grip because of their failure to take account of human nature. The false beliefs of Rousseau as to the "State of Nature" introduced an ugly ferment into the social organism. A colorless Deism was offered in place of established religion. The logic of nationalism was beginning to construct its syllogisms, which have since led us into such an impasse.

It was in these surroundings that Darwin was excogitating his theory. Finally, in 1859, stimulated by Wallace's independent discovery of the principle of Natural Selection, he gave his views to the world. The effect was, from the first, enormous. It was at once seen that science had here dealt the shrewdest blow she had yet struck at the old system of thought, and that the issue was now joined in earnest. It is true, of course, that she had already accomplished a great deal in the same direction, notably in regard to astronomy in the seventeenth century; and this had contributed to produce the scepticism of the eighteenth century. But the conflict had been almost entirely on the fringes of human life, or we should say on the fringes of the relation of reality to man. It had concerned reality on the physico-chemical plane alone.

Even the sceptics and the liberals in the matter of intellect, those who thought they had emancipated themselves from the superstitions of the traditional system, were still captive to its central idea, which it had hardly occurred to them to question. They still lived and moved and had

their being in the anthropocentric assumptions which had been man's since he first began to systematize his thoughts. The world—a static world—had been, it was assumed, arranged for the benefit of man: it was scarcely considered except in relation to his needs or wishes.

It was with these assumptions that the scientific system of thought now came into conflict—a conflict that will always be associated with English names above all—Lyell, Darwin, Spencer, Hooker, Huxley and Wallace.

It may be quite true to say, as has often been said, that Darwin was not the first evolutionist, that he was not the first to try to remove man from his umbilical position in the scheme of things: that his achievements would have been impossible without a long line of predecessors in other sciences such as astronomy and geology, and an ample band of helpers in his own age. Granted: but it remains that Darwin did as a matter of fact succeed where others had failed, and that his own work was the pivot on which the whole movement turned.

How can I sum up Darwin's achievement in a few sentences? In the first place, then, he substituted natural causation for the non-causation of supernaturalism in biology. He for the first time, with his doctrine of natural selection, made it possible to understand how all the different species of animals and plants could have been gradually evolved from common ancestral forms, and how the apparent design of adaptive structures and habits could have come into being without a Designer.

In the second place, while not the first evolutionist, he was the first to make the acceptance of evolution an intellectual necessity to all those willing to judge evidence on its merits. He assembled a vast and indeed amazing bulk of evidence from the most diverse sources, evidence which

was intelligible on the evolution theory, unintelligible on any other. By so doing, in addition to his demonstration of a possible method of evolution, he established the existence of evolution as a fact.

He thus substituted a dynamic for a static view of things. True again that Laplace, Kant and others had been doing the same for astronomy, Lyell for geology, and a number of thinkers for certain aspects of history: but without this final and most difficult proof for biology a connecting link was missing and the dynamic conception of the world as a whole was impossible.

The world then moves: progress exists. There was a time when man was not: a previous time when birds and beasts were not: still further back, no land animals—in the remotest past, no life. And there we link up with the geologist and astronomer, who finally convince us that what is the remotest past to the biologist has far further remotenesses for them, and conduct us back to time when there was no earth, and before that no sun.

Man then may be, and still under the Darwinian dispensation is, the crown of creation: but he is the present crown only, not the utmost possible. There is no more reason for his persistence as the highest product of life than there was for the persistence of the ape or the reptile or the stegocephalian as the highest product. They were superseded by their own descendants. Shall this fable of Zeus and Chronos not come true for man as well?

Galileo had taken man away from the spatial centre of things. Darwin removed him from the temporal and the ideal as well. But he is restored to a psychological centre —as the only part of the cosmos known to us where there is understanding, the only part where even an attempt is made

to grasp phenomena as a whole and to discover meanings in things.

But we must return to our pure biology. Darwin's work was an immense stimulus to comparative research, particularly in the field of embryology. Here resemblances could be traced between the early stages of one organism and the final stages of another; and so development could be regarded as an obscure but none the less decipherable palimpsest recording the æons of racial history. Comparative work was also extended into the past by the direct method of palæontology, and by this means, too, a flood of light was thrown upon phylogeny, or the science of animal descent. But by 1900 comparative anatomy and comparative embryology were in sight of the confines of their kingdom; there remained only small gaps to fill in; and yet it was clear that, save within one or two groups, the detailed relationships of the main groups were still and would forever be unrevealed, lost in the archæzoic ages of the youthful earth. In addition, it was realized that comparative study alone can never say the last word as to the *method* of evolution.

Physiology in the customary sense—the working of the adult body—meanwhile continued on quite other lines. Among general principles, she demonstrated, first through Wöhlers, that organic compounds were not peculiar products of living bodies, but could be manufactured in the laboratory. She showed, by the aid of Pasteur and Tyndall, that spontaneous generation, even of the humblest creatures, did not occur. Through Claude Bernard, she began to gain an idea of the chemical economics of the body, of the essential part played by regulatory processes in the organism, and of the means, humoral as well as nervous, by which correlation of parts and persistent individuality were main-

tained. Later she gives us the construction of balance-sheets of energy and of substance in metabolism; the investigation of the rôles of different classes of food-stuffs; the distinction between the metabolism of energy-production and that of repair and maintenance; the mapping of the nervous system, with the discovery of cerebral localization; the discovery of hormones; the investigation of the effects of external agencies such as temperature, mineral salts, light, etc.; the detailed working out of all the amazing delicacy of regulation, as regards respiration, chemical composition of blood, or temperature; the investigations, again started by Pasteur, of immunity and other protective mechanisms of the body. And last, but by no means least, the analysis of process upon process to depth beyond depth of physical and chemical explanation—the fuel and energy cycle of muscle; the mode of conduction of nerve; the chemistry of the hormones and other secretions; the mechanism of the transport of gases in the blood; and all the hundred-and-one other triumphs in the realm of the physics and chemistry of life-processes.

Roughly summing up, we may fairly say that whereas before Harvey no intelligent physiology was possible, and before Bernard only a crude first approximation, to-day we have a reasonable knowledge of the biological function of every organ in the body, a general idea of how the body works as a whole, as an organism, and an ever-increasing insight into the physico-chemical processes underlying biological function.

Another discovery of general importance was that of the extreme specificity of organisms. By immunity reactions, precipitation tests and the like, it was shown that not only was animal group to be distinguished from animal group by the reactions of its proteins, not only single

species from single species, but also in some cases individual from individual. Similar results were arrived at by the study of variation in general, confirming those of every-day inspection of the human species; in all probability no two individuals, at least of any higher animal, are exactly alike; and the differences are certainly in the main constitutional, innate.

Meanwhile quite separately, and indeed itself along several separate approaches, the atomistic idea had been invading biology. In the first place came the discovery of cells, and, in the '30's of the last century, the great generalization known as the cell-theory, with its conclusion that all organisms are made of the same kind of units, and that these units always arise by division of pre-existing units—*omnis cellula e cellulā,* as Virchow had it. If this turned out to be too sweeping in one or two details, it is yet essentially true. Next came the discovery of chromosomes —first of their existence, then of their constancy as units of lower grade than the cells, they too self-reproducing.

Meanwhile speculations had by no means been lacking as regards units of still lower grade, units which should in some way be the controllers of the processes of life. The most audacious of these was Weismann's, who anchored his soaring balloons of theory to the solid facts of the chromosomes and their behavior.

Meanwhile, all unknown to Weismann, Mendel had actually demonstrated the existence of such units, and shown what their effects were. Forty years later, his results were confirmed and extended by Bateson, Correns, Tschermak, Baur and a host of others; and finally it was reserved for Morgan, Bridges, Muller and Sturtevant working in co-operation to show that these unit-factors were actually lodged in the chromosomes in a definite order and definite

proportions. Weismann, though entirely off the track as to the arrangement and mode of action of the controlling factors, had, with a flash of genius, been right in connecting them with the newly-discovered chromosomes.

The present state of our knowledge is this—we must postulate that the development and nature of each organism, in so far as dependent upon inheritance, is almost entirely under the control of these apparently ultimate biological units, the factors or genes. For each higher organism there are hundreds, perhaps thousands of these. Each has its station, or locus, in a particular chromosome, and in a particular place within that chromosome, so that it always has the same neighbors. Each has its own particular work to do in development; but the result of this activity may be different in different external environments, and different with different combinations of neighbor genes —in other words, with different internal environments. For it should never be forgotten that a gene cannot exist or act isolated, *in vacuo,* any more than a chromosome—or an organism; it is a unit which achieves its results by coöperation with others. None the less it is certainly unitary, in the sense that it preserves its nature and its place, and may be distributed in heredity independently of any other particular gene.

Genes, too, may, though rarely, become altered: this change is called mutation, and once a mutation has occurred, the mutated gene is as stable as it was in its original phase. One of the most important facts discovered in recent years is that single-gene mutations may be of all gradations in extent, some being violent in their effects, such as that which at a bound causes winglessness in a fly, others only producing slight changes in eye-color or in the shape of some bristle, effects so slight that without careful analysis they

would be mistaken for fluctuating variation, and may indeed often be overlapped by the effects of the external environment.

Thus, through Mendel, Bateson, and Morgan we reach a definite viewpoint. Any given organism has a chemical basis of extreme complexity but of perfectly definite construction, which, if our knowledge were but adequate, we could write in a formula after the fashion of the organic chemist. The genes of which it is composed are self-reproducing, potentially immortal, unchanging save for occasional mutations which appear always to be of definite though generally of small extent; but owing to the distributive machinery of heredity, given in the reduction of the chromosomes and the reunion of reduced sets at fertilization, and in so-called crossing-over, they are always being shuffled and reshuffled, combined and recombined, so that in sexually-reproducing organisms in which inbreeding is not the rule, it is extremely improbable that any two individuals (save so-called identical twins) will possess identical gene-outfits.

This last point is of interest, for it leads us back and shows us a material basis and a reason for the specificity of individuals which we had empirically discovered by other means. Each of us individuals is in one sense a chemical individual.

Meanwhile quite independently the study of development had pursued its way. One of the first great generalizations in this field, beyond the generalizations of descriptive and comparative embryology, was that of Roux which he christened *Der Kampf der Teile*—the struggle of the parts. This, indeed, is a principle of universal application in functional biology, although its most interesting applications are to the development of structure. Roux had the vision

of the equilibrium of the body as an equilibrium of struggle, each tissue and each cell competing with the rest for food and for opportunities to reproduce just as do whole organisms in the outer world: it was in fact an extension of Darwin's principle of the struggle for existence from whole organisms to their component parts.

This principle, of a balance of power within the body, which may be tilted this way or that by circumstances, but in general results in a particular equilibrium, has proved of the greatest importance and has been amplified and extended in various ways. It has helped to illuminate the detailed adaptations of structure to function seen in tissues like bone or sinew. Those cells which are exposed to a certain degree of tension-strain survive and reproduce better than those which are over-strained or not strained at all. It helps us to understand the results of starvation experiments, in which some tissues are used up while others are maintained relatively untouched. As a result of regeneration experiments, we have been compelled to extend the idea of equilibrium and postulate a "form-equilibrium" to which in normal cases the mutilated animal returns by its regenerative growth. It has been employed in studies on malignant disease, which have made clear that epithelial and connective tissues are in a real sense antagonistic, struggling with one another, and that if the equilibrium of struggle is upset, disaster is the result through the over-multiplication of the victor.

Meanwhile another very important principle, that of gradients of physiological activity or developmental energy, was emerging. An adumbration of it had been forthcoming early in the nineteenth century, when it was noted that in embryology a wave of development and differentiation invariably proceeded from the head to the tail end. Later,

it forced itself upon the attention of the pioneers in what the Germans call Entwicklungsmechanik, those who try not only to describe development but to unravel its causal chain. Boveri in particular, in the '90's, drew attention to the graded stratification of the yolk and other material in the eggs of various animals, and the correspondingly different destinies of different regions. Later the pure physiologists showed that similar gradients of activity occur within various organs of the body of the highest animals, such as heart, intestine and uterus. The rhythm of the beat of an isolated strip of intestine, for instance, is higher the nearer it is to the stomach. Finally Child has given us a comprehensive theory of the subject, combining facts of development, of physiology, of regeneration, and of behavior.

It is now clear that these gradients of activity are of the utmost importance, especially during development. Certain structures can only appear at certain levels of the gradient, and the gradients determine the first and crudest ground-plan of the animal by imposing upon it its symmetry-relations. Not only this, but the most active region of the gradient in some sense dominates over the other, and determines the way in which they are to develop. In the most general way, the idea of *potential difference,* much as in current electricity, must be taken into account by biology.

Other work on embryology has been actively prosecuted, with the result that we now know in general what are the chief distinct periods of development and the chief methods employed during each. First, in vertebrates and as a general rule in unspecialized forms, comes the period when the gradients are all-powerful, and the egg is being divided into cells. Then that during which chemical differentiation is at work, and the embryo becomes a sort of chemical mosaic of regions each predestined to develop in one particular

way. And then a final period in which the effects of hormones, of nerve stimulation and of function begin, and the rough outline is molded into the final shape.

Through the new technique of tissue-culture we have learned much of the potentialities of different tissues; and studies on regeneration and particularly transplantation have been especially valuable. Finally, as was natural, it has been through developmental studies that the time-element has been introduced as fundamental for biology. We must not only know how to describe events, and to give an account of the kinds of processes which underlie them—we must know the rates at which they happen, for comparatively small relative differences in the rates of two processes may cause large differences in the end-results which they determine. In the same way, if I lived on my capital and if my spending and my income were both at the rate of five per cent, it would make a very great difference to put my income interest-rate up half a per cent, and my expenditure rate down by the same small amount.

There is one last and somewhat other aspect of development—the development of the race. This problem is now being attacked along two lines. In the first place, genetic knowledge makes it possible to plan experiments designed to throw light on evolutionary change; in the second place, palæontology has advanced so far that it is often possible to construct very finely-graded series of links along various evolutionary lines, thus showing in considerable detail the kind of course which evolution has actually pursued (though of course giving no clue as to its method). If we could but construct a geological time-scale, whether absolute or relative, we should be able to analyse the rate of evolution and see to what kind of curves such evolutionary processes as the elongation of a limb, the reduction in number of a

series of digits or teeth, or the increase in bulk of the animals as a whole, were conformable. But here, zoölogy must wait upon geology.

I could have pointed out numerous other lines on which advance has been made; but what I have enumerated is amply sufficient for my main purpose—namely, to show that the time is ripe for a new synthesis, aiming at a unified biology, and a synthesis in which the dynamic point of view is destined to play a very important part.

Let us resume. Biology in her divergent branches has not only amassed a supply of ordered and tested knowledge, but has been able to discover a series of general principles. She knows in general what are the characters of different animals and plants; she has an adequate working conception of the evolutionary relationships of the various groups; although she will doubtless pierce far deeper, she can put forward a coherent account of the principles on which the animal or plant body works, a first approximation to a comprehension of it as an organic machine. She has penetrated to a knowledge of the mechanism of heredity, which she finds surprisingly similar in the most diverse groups both of animals and plants, finding everywhere an orderly arrangement of separable factors with a peculiar kind of shuffling and recombination at each sexual act. And she has a knowledge of the *what,* and a first approximation to a knowledge of the *how,* of the elaborate process of development from the egg, together with much knowledge drawn from studies in regeneration, in grafting, in ecology, in pathology, in tissue-culture, of the reactions possible to living tissues under abnormal conditions.

Each one of these main lines can be investigated more deeply; but now that we have some coherent knowledge

of the general principles in each, the most fruitful advances will be along the border-lines, and will consist in linking up one set of principles with another. If we can link up Mendelian analysis with the facts of palæontological succession, and with those of ecological study of animals in the field, the evolution problem ceases to be academic and becomes alive; if we can successfully submit the processes of development to the same physico-chemical analysis which has proved so fruitful in the physiology of the adult animal, we not only open vast fields for research, but drive vitalism from one of its few remaining strongholds. If we can link genetics with descriptive anatomy by showing *how* Mendelian factors operate during development to produce their final effects, we shall have vivified two static conceptions and made them dynamic, and shall have put much more meaning into both of the somewhat dry subjects of factorial analysis and of systematic description.

In brief, every biological fact now can have significance for a number of separate biological disciplines, and can be examined by a number of methods in the light of several very different sets of guiding principles. Within the next few decades it should be possible to write a treatise on the principles of biology (real brass tacks, and not merely evolutionary speculation!) as it is now possible to write a treatise on the principles of physics.

Let us remember that this advance is of recent date—so recent that what I have written would certainly not have been true in 1900, and would have seemed extremely temerarious in 1914.

Before closing, I might, perhaps, give one or two illustrations to drive home my claim that the unification of biology is now beginning. Let us first take some particular character of some particular animal. I will choose one

familiar to all—the fine feathers of that fine bird, the domestic cock. The systematist describes the varieties, and is able to show that they are all descendants of one wild species, the jungle fowl, *Gallus bankiva,* which is different in a number of peculiarities from its near relatives, *G. sonneratus* and other species of the genus. Going into their distribution, he finds them all Oriental, and concludes that they have evolved somewhere in this Indo-Malayan region. Studying their habits in a wild state, he finds that the males take no part in nest-building, incubation, or the rearing of the young birds, and that they show polygamous tendencies, some males going about with bands of two to four hens, though others have to be content with one. He further finds that the females offer a fine example of protective coloration, and that the male indulges during the breeding season in a special display—familiar enough to all who have looked on at the spectacle afforded by a farm-yard—before his mate or mates. Phenomena like this last stimulated the mind of Darwin to his great generalization of sexual selection—to the view that the evolutionary origin of the bright colors of male birds is in general to be sought for in some advantage conferred upon their possessors in stimulating the female to mating. In other words, that the selecting sieve for such epigamic characters used in display is the mind of the opposite sex.

Then comes comparative study, and finds that, in general, the type of display and of coloration, and the degree of difference between male and female is in high degree correlated with the mode of life of the species. In polygamous species the males are brightest and most fantastic, the females most thoroughly concealed; where, as in the song-birds, monogamy prevails, and the rôles of male and female are still diverse, but there is biological necessity for

both to take a share in feeding the young, then, though males alone still perform in display, they will never be so strikingly different from the females, since there is now a greater premium upon a longer preservation of the male from his enemies. Where both sexes share all the duties of reproduction, then we often find close approximation in color and plumage, and in behavior too, leading to a mutual display in which both sexes participate, instead of a unilateral display by male alone. Where the species nests in holes, then both sexes tend to be bright-colored, although only the male may display; those species of song-birds that nest where there are trees, sing from a perch on some prominent bough, while those, like pipit or lark, which breed in treeless places, have evolved a special aerial flight during which the song is given, in order that the song may be equally conspicuous. He thus arrives at the conclusion that in broad outline the type of plumage employed in display is under a double evolutionary control—partly that of sexual selection, partly that of natural selection, and that it is adapted in the biological sense to the rest of the conditions of the bird's existence. Thus the plumage of the male of any domestic breed of fowl is unintelligible except in the light of history—its descent from that of *Gallus bankiva,*—and also in that of ecology—the mode of life of *Gallus bankiva* in all its multifarious relations with things and with other lives.

The physiologist next steps in. He finds that the male display-characters are controlled by hormones, the secretions of part of the reproductive organs. In the cock the male head-furnishings and instincts depend upon the secretion of the testis, while the secretion of the hen's ovary acts in the opposite direction and inhibits the development of

male plumage. The biochemistry of the subject is yet in its infancy, and holds great promise for the future.

The pathologist further finds that aged hens, when their ovaries atrophy, develop male plumage according to physiological expectation; but that in other cases, when the ovary is the seat of certain types of tumor, the transformation may be complete, and the one-time female may be changed into a bird that is functionally male, thus shedding valuable light upon the potentialities of sex-transformation, and upon human sexual abnormalities.

Meanwhile the geneticist has been at work. By a study of sex-linkage, he has been able to show that sex in birds must be determined at fertilization, by means of the ordinary sex-chromosome mechanism in which one sex possesses two sex-determining chromosomes, the other only one. In this whole group, however, so far as tested, the usual state of affairs is reversed, since the females have an unpaired sex-chromosome, the males a pair of them; and this has been visibly confirmed by the microscope of the cytologist. Meanwhile hybridization experiments—not with fowls, it is true, but with pheasants—have been showing that the individual factors for the male plumage-characters cannot most of them be sex-linked, but are in the other chromosomes or autosomes. We thus begin to get a picture of the mechanism controlling sexual characters. The chromosomes are the primary switch: they normally determine whether an animal shall be male or female. The first sex-character which they determine is that of the reproductive organ—ovary or testis. This, once determined, functions as a second switch-mechanism, for it produces a secretion which controls the expression of the remaining or secondary sex characteristics. And it must do so by means of establishing one or other of two internal environments, the

one permitting the factors for male plumage-characters to appear, the other inhibiting these and allowing expression of the factors for female characters.

Given time and breeding facilities, and the prospect opens before us of mapping the factors in the chromosomes of the fowl as has been accomplished for those of Drosophila. Indeed, a start has already been made with the sex-linked factors in the sex-chromosome.

Then comes developmental physiology. It asks itself what is the difference between male and female embryos which causes one to form testis, the other ovary; it asks what is the chemical composition of the male and female hormones, and the modes of their action on the tissues. It studies the rate of growth of the comb in male and female and finds the interesting fact that in the male during puberty the comb is growing faster than the rest of the body, the ratio of the two rates being constant. It finds that in the female the comb shows spurts of growth preparatory to each laying-period, coincident apparently with changes in blood-pressure, and probably also, according to Riddle, with changes in the activity of the adrenal glands.

Then comes the question of the actual feather-pattern. One very important fact revealed by genetics is that whole zones of the body behave more or less as units in regard to type and marking of feathers—the neck, the breast, the saddle, the crests, the tail and so forth. Each of these areas is sharply delimited in its reactions by some as yet unknown mechanism. A single feather growing on the border-line between two zones may show the characters of one zone in one part of its web, those of the other in another part! The actual pigmentation of the feathers leads us into most interesting problems of the chemistry of pigments and of enzyme-action. Certain genetical fac-

tors are responsible for one type of enzyme-action and one type of pigment-result (such as black), others for another type (such as red). So-called extension factors limit the pigment changes to particular areas: intensity factors dilute or intensify the color; modifying factors introduce small changes which simulate fluctuating variability. Further analysis shows that many of the typical patterns of feathers, such as barring, depend upon simple physiological rhythms like the alternation of day and night and consequent rhythm of nutrition and activity. Intermittent feeding and other tampering with the normal rhythm will alter the pattern produced. Factors involving rate of development also enter into the picture. Rate of growth in weight and rate of attaining sexual maturity appear, for instance, each to have independent genetical bases. The final mean absolute size of a fowl is therefore dependent upon the interaction of these two factors (and probably upon others as well).

I will give an example or two more before closing. Take the question of cancer. Cancer is a biological problem—the problem of the escape of cells and tissues from organic control. It can be fruitfully attacked along a number of wholly separate lines. To begin to investigate it scientifically, a fully developed histology is needed—a descriptive method. Peyton Rous, followed by Gye and Barnard, have shown the advantages of the methods of bacteriology and special extensions of those methods. The experiments of Murphy in grafting mammalian cancer on to the embryonic membranes of chicks within the egg used the methods of experimental embryology, and showed not only that there is no resistance to the growth of foreign tissue before a certain stage of development, but that resistance when it came was due to the spleen and other lymphoid tissue.

The conception of the body as an equilibrium of struggle led on to various interesting investigations. In the first place, many workers see the epithelial tissues at constant war with the connective tissues and believe that cancer is always due to a failure of this beneficent balance of power. Then, in female mice, a transplanted malignant tumor will not grow while the mother is pregnant—the competition of the embryos for nutriment is too strong. The use of X-ray and radium treatment is based on an extension of this idea—the malignant cells, because more actively growing, are more susceptible to the effects of the treatment, and when thus damaged cannot hold their own in the struggle. Guided by such ideas, we must also clearly try to see whether there is no way of stimulating the resistive mechanism of the body so that, like the embryos in the mice, it becomes dominant over the tumor. Then the work of Warburg has shown that the respiration and energy-cycle of cancerous tissue is extremely different from that of ordinary cells, but that the extremes are connected by all gradations, through benign tumors, embryonic cells, and young growing tissues. Here we are introduced to the whole question of energy-production in living cells, a study involving every refinement of physical and chemical method for its study, as an elementary acquaintance with the work of such men as Hopkins, Hill, Warburg and Meyerhof will testify. Not only this, but it opens up possibilities of control by chemical means. The studies on the problem of cancer by external agencies, such as Nematode parasites and tar, introduce us to new questions—the degree of modifiability of cells by their environment. Here pathological anatomy can make its contribution, as can the zoölogists' studies on regeneration, those of the experimental embryologist, and by no means least those of the workers on

tissue-culture who *in vitro* can examine the effect of one particular salt or one particular hormone on one particular tissue or another without the complications of the whole body. And genetics will not be denied. Some strains of mammals are much more susceptible to standard tumors than others, and the susceptibility depends on segregable Mendelian factors. In Drosophila, the Morgan school have actually found a mutation which causes death during development through the agency of a hereditary tumor.

These are but a few of the lines of approach to the problem. It is at present impossible to know along which line the solution will lie, but it is probably safe to prophecy that it will come through concerted advance along several.

One more example, and I have done. You will excuse its personal nature, but sometimes one's own work is the most illuminating, because one knows one's own false starts.

Some years ago, impressed on the one hand with the power of the ductless glands, and on the other with the brilliant analysis, by my lamented tutor Geoffrey Smith, of the development of sex-characters in Crustacea, I thought that it might prove possible to test his theory that the difference between the sexes was more a matter of general metabolism than of a specific hormone, by feeding crabs with thyroid tissue, and seeing whether its great activity in increasing basal metabolism would modify the female characters in the direction of maleness. This attempt ended in wholly negative results. I kept young crabs on an exclusive diet of fresh thyroid for periods up to eighteen months without there being the least effect on health, growth, moulting, or sexual characteristics. In passing, a German worker, Romeis, has just demonstrated that there is a reason for such negative results. For whereas in vertebrates on a thyroid diet the active principle

passes unchanged into the system, in crustacea it is attacked and broken down by the digestive glands, so that feeding experiments are foredoomed to failure. It remains, of course, now to try injection experiments.

Meanwhile, however, in order to see whether the endocrine substances had any effect, I had to establish the norm for the secondary sex-characters chosen—in this case the size of the abdomen. Here I made what was to me the unsuspected discovery that, whereas in the male the ratio of the breadth of the abdomen to the total breadth of the animal is approximately constant throughout life, that of the female is continuously changing: it begins by being of the same relative size as in the male, and from that point on becomes continuously larger. In other words, the female of the common shore-crab has no fixed form, no constant proportions which one can speak of as typical or adult.

Pursuing this interesting line of investigation, I found that precisely the same, *mutatis mutandis,* held for the male of the fiddler crab, Uca (Gelasimus), in which one of the great claws, beginning from the female type, increases in relative size throughout life. I was here further able to find a definite mathematical expression relating the weights of the claw and of the rest of the body. The two behaved like two sums of money put out at two different rates of compound interest: in other words, the *ratio* of their growth-rates was a constant. From this fact, a number of lines branch out. First come problems in biological dynamics, in the balance of parts. What will happen to the growth-rates of body and of big claw if the big claw be cut off and made to regenerate? This experiment remains to be performed. Then come problems of systematics. I was able to show, in the case of a certain stag-

beetle, that the size of the "horns" or mandibles followed the same law in relation to that of the body, and further, that five "varieties" which had been established for types with different kinds of mandible were really not distinct at all but were merely arbitrary assemblages cut out of a continuous series, the first so-called sub-species being merely an assemblage of the smallest-bodied individuals, which therefore had the relatively smallest jaws, the last comprising the largest-bodied with the relatively largest jaws, and so on.

The facts have also their bearing upon evolution. If the formula I found were to continue to hold good, and if the fiddler-crabs were capable of growing to greater absolute size, then the large claw of the male would soon reach an intolerable unwieldiness. For instance, a male fiddler-crab whose body without large claw weighed a kilogram would have to possess a claw weighing over ten kilograms —"which", as Euclid puts it, "is absurd". As a matter of fact, no species of fiddler-crab does grow to a size at all comparable with that of the shore-crab or the edible crab or some of the spider-crabs: and the reason, I take it, is that the existence of this type of growth-mechanism for the claw has prohibited any such size-increase during evolution.

It is interesting to find that the same type of law appears to hold good for the antlers of deer and probably for the horns of other ungulates. If so, the fact that in groups like the Titanotheres, whose fossil history has been so well studied by Osborn, horns appear independently in several lines of evolutionary descent at a certain size, need not at all mean, as Osborn has assumed, that their evolution has been an *orthogenesis* in the strict sense of that word—namely, that their original hereditary constitution was so

constituted that it was predetermined to produce factors for horn-development separately in all the evolutionary lines within the group. On the contrary, if horn-growth depends upon such a developmental mechanism as I have outlined, with the additional proviso that the first appearance of horns only occurs at a certain "threshold value" of size, then increase of size, which undoubtedly is of evolutionary advantage up to a certain high limit, will automatically cause the appearance and later relative hypertrophy of the horns. In the famous Irish Elk, it becomes probable that the reason that the relative antler-size became so enormous that the animal could be readily rendered extinct by slight changes in conditions was merely due to the great absolute size of the animal as a whole.

With the question of antlers and horns we are again brought up against physiological problems, for their growth is controlled by the secretions of the testis and probably by that of other ductless glands as well. And we are also brought up against genetics, since it is well established that slight differences in form, types of branching, etc., in antlers, are due to small differences in hereditary constitution.

I could dilate further upon the subject, but enough has been said to show the various aspects under which one set of characters must be considered. There is first of all the simple descriptive method, and the comparative-descriptive. There is then the historical, or descriptive-evolutionary, aspect; there is the character's function, its utility to the organism—an aspect which can only be adequately dealt with when ecology, in the sense of the scientific natural history of the species, is considered; there is its mode of functioning, as unravelled by physiology and stated so far as possible in terms of physics and chemistry; there is the

genetic aspect—the question of the hereditary units responsible for its development; and there is the analysis of individual development, linking with its dynamic the two static viewpoints of pure description of character on the one hand, pure factorial genetic analysis on the other, and involving considerations of change of equilibrium and of time which are more or less neglected in all the modes of attack hitherto mentioned. Finally, there is the analysis of racial development, or the causal-evolutionary aspect, attempting not only to describe the course of evolutionary change, but to understand its methods. What is more, some progress has been made along all these lines, and each one is immediately vivified by the application of methods and ideas drawn from another, each immediately tends towards narrowness and fossilization without such methods and ideas.

Genetics, *sensu stricto,* is, without developmental physiology, merely a new morphology, the morphology of the chromosomes, drier and more technical than the old morphology of adult structure. Developmental physiology without genetics, on the other hand, is liable to make oversweeping generalizations, and without physics and chemistry is apt to become speculative. Pure description by itself becomes a kind of meaningless stamp-collecting. The evolutionary viewpoint uncorrected by those of physiology, embryology, and genetics, becomes (as zoölogical science experienced towards the close of the last century) a welter of arm-chair generalizations and unverifiable hypotheses. On the other hand, the physico-chemical analysis of pure physiology becomes *mere* physics and chemistry, and ceases to be biological at all, if it neglect to keep in mind the organic and functional aspect of things; while functional analysis and developmental physiology will often either

push adaptational views too far, or else be baffled by apparent non-adaptation, if they do not study the history of the species with which they deal, since so often the possibilities of the present are limited by the mortmain of the past. In brief, specialization has brought about a situation in biology in which specialization alone will be of no great value. The specialist must either have some knowledge of other lines of work, or he must combine forces with other specialists in his attack upon particular problems. The wheel has come full circle, and biology, from being a series of unconnected streams, is become a unitary science in which any fact in any branch can become a key to problems in other branches.

What this means is that biology has not merely left its childhood far behind, but has entered upon its maturity, in which the main lines of its character have been already laid down; however, there remain to realize, by the labors of a heroic prime, the fruitful results which that character confidently leads us to foretell.

And the moral? The moral, I take it, is that we should set about adjusting ourselves to this new biological outlook, for the first time truly unitary, and construct a body of general principles and a course of instruction for biological students which shall impress them with this unity, which shall give them practice and confidence in the use of all the various methods available—descriptive, systematic, ecological, statistical, psychological, physico-chemical, genetic, developmental and the rest. Only so will they not be intimidated by the vastness of the field and shrink into a shell of specialization which deliberately aims at a false completeness within itself, but rather, like Jacques Loeb, always see *problems,* and go forward with a brave heart to attack those problems by whatever methods are available.

II

APPLIED BIOLOGY

MOST laymen seem to imagine that men of science pursue their subject because of the practical ends in view. Science, as reflected in the popular press, would appear to be a modern version of Santa Claus. Surrounding herself with a good deal of complicated apparatus and appropriate laboratory odors to give the atmosphere of the magician, she is busily engaged in devising telephones, aëroplanes, miraculous cures for disease, new forms of vegetables, radio sets, elixirs of life, and other trifles of which the rest of mankind can make use. That is her *raison d'être*, and the hope of serving the community by presenting it with a new toy which really works is the scientist's inspiration and the mainspring of his work.

Such a picture is singularly far from the truth. The man of science pursues knowledge because to him the pursuit of knowledge and the discovery of new truth are the breath of his nostrils. He devotes himself to research for precisely the same reason that the poet devotes himself to the arduous business of writing poetry, the explorer to the dangers and hardships of unknown lands, the mystic to the time-consuming rigors of the devotional life, or the mother to the never-ending service of her child. He is reasonably content with a salary which a civil servant or business man of the same calibre would laugh at, he is often prepared to work in the laboratory all day and spend his evenings in the labor of reading or writing—Why? Because the

discovery of new knowledge is what above all else interests him, what alone gives essential value to his work.

He is not, to be sure, uninfluenced by considerations of practical utility. The poet hopes that other men will read his poems and thereby come to richer life; the explorer doubtless reflects that his new lands may be colonized; the mystic believes that his ecstasies help and inspire in the business of every day; and the mother wishes her child to grow up a useful member of society. But mothers may still love their children when they are puny and weak, when they are stupid or base, when they grow up to vice or crime. They love because not to love would be to repudiate their own natures.

And it is so with the rest of my examples. Not to attempt what he is attempting would be to each a renunciation of the best part of himself, a burial of his one talent wrapped in the napkin of opportunism.

To many that will be a hard saying: but it is true for all the highest activities of human nature. They are pursued as ends in themselves, for their own values, which are above the values of the so-called practical life of every day.

Luckily, however, the world is so constructed that practical results do flow from knowledge, for whatever reason that knowledge may have been pursued. That this is so is a part of the essential reasonableness of life—its different parts do cohere, however difficult it may sometimes be for us to see the connection. Examples are infinite. Galvani fiddling about with frogs' muscles and strips of metal, Faraday in his dingy basement at the Royal Institution—without them you would to-day have no electric light, no telephone, no dynamo. Newton's apple is probably mythical, but, certainly, without his passion for understanding the courses of the stars, we should be without the nautical

almanac; without his devotion to pure mathematics, the calculus would have been far slower in its coming, and the whole progress of science would have been different and feebler. And without poetry and music and other art, life to many would be hardly worth living. No need to multiply instances: it is enough (though that for most men seems hard!) to understand that life from highest to lowest manifestations is one, that to despise or belittle any part of it is wrong and foolish. It is as foolish to belittle pure science because it is unpractical, or poetry because it is visionary, as it is to despise the body because it is not the soul, or be contemptuous of the common man because he is not the uncommon man. Love flowers out of simple sex; art out of everyday emotions; mind depends on brain, and brain on food and drink. It is a too common sign of mediocrity and false culture to disbelieve in the values of what is higher than itself, and at the same time to despise and try to put out of sight the lower things which are yet the foundations on which it is built. Philistinism and snobbery, narrow-mindedness and prudery—they all go together.

But to the business in hand! Science advances by the search for knowledge for knowledge's sake, but the knowledge spills over into practice as the years advance. Our business is to see how in recent years biological knowledge has been applied to practice, and what new advances may be expected.

The first spectacular applications of modern biology have been in the realm of disease-prevention. Pasteur followed up his final demonstration that spontaneous generation does not occur with the discovery of its corollary—to wit, that infectious diseases, such as typhoid, diphtheria and pneumonia, were caused by living organisms, or, as they are sometimes styled, disease germs. Most of these

so-called germs belong to the bacteria, the simplest known organisms, capable of multiplying two or three times an hour. Modern research has shown that some others, like that of measles, are ultra-microscopic, too small ever to be seen. Still others are of animal nature, like the active causes of malaria and sleeping sickness.

Hand in hand with this went our knowledge of parasitology. In the first place the life-histories of many of our larger parasites were unravelled, with the result that it has been possible in many cases to break the weak link in the life-chain and to stamp out that particular disease and discomfort. That is true in civilized countries for tapeworm, roundworm and trichina: and the hookworm and other enemies of the fullness of human life are following in their wake. But later it was found that there was frequently an association between some parasite or other noxious animal and the microscopic agent of some disease. Rats harbor fleas of a particular sort, the fleas harbor the bacilli of plague, and so is plague spread throughout mankind. Ticks spread spotted fever, mosquitoes give malaria and "Yellow Jack", flies may infect our food and our persons in a dozen ways.

So arose what for brevity's sake may be called the germ theory of disease. Any given disease was supposed to be due to a given organism, large or small, animal or plant: if you could exterminate or weaken the germ, you could get rid of the disease. The triumphs of serum-therapy—vaccination, and other forms of immunization—again largely due to Pasteur and later to Ehrlich, showed how the enemy might be circumvented even when it was impossible to annihilate him: and a period of optimism dawned.

The germ took hold of scientific and popular imagination alike. To medicine, the problem of disease seemed

enormously simplified. Disease became something extraneous, to be fought and killed: bacteria were simply the enemy. The popular mind took this idea and clothed it to suit its own taste, as it clothed mediæval Christian theology. Germs, instead of the dull-looking rods and dots of bacteria that they really are, became microscopic monsters, scientific devils: but in the popular mind, too, the germ-theory revived in matters of health the old crude ideas of external warring powers of good and evil.

The particular brand of optimism based on the germ-theory is passing away. The pioneers had forgotten that as it takes two to make a quarrel, so it takes two to make a disease. They had left out of account the human organism.

We now know that the reaction of the organism is as important as the nature of the parasitic "germ". We all of us seem to harbor the bacillus of tubercle: but only a small percentage develops tuberculosis. Measles, with us an unpleasant disease of childhood, wiped out whole populations when first introduced among the South Sea Islanders. Why? Because their natural inborn resistance was less than ours. We now know that to every disease-germ there are very different grades of inborn resistance, and further, that any of these grades may be increased or lowered by outer circumstances.

While some diseases may, therefore, be totally eliminated by the extermination of the disease-germ itself, or, more usually, by breaking a link in the chain by which the germ is transmitted, there are others in which, so far as we can see, it will forever be impossible to destroy the microscopic and elusive bacillus; and, if we wish to prevent and not merely to cure, we have to rely on the raising of resistance.

The first method has, however, had its notable triumphs. Malaria, smallpox, yellow fever, bubonic plague, sleeping sickness—there we have a few of the plagues which have been almost expelled from the civilized world and will slowly but surely fade from the uncivilized as well.

This method of control by extermination can be extended not only to larger parasites, but to all animals noxious to man. Given time and a little trouble, we could make for ourselves a world without centipedes, tarantulas, scorpions, biting insects and poisonous snakes as effectively as the United States Health Service has rid the Panama Canal zone of the microscopic organisms of malaria and yellow fever.

As an example of what may be done in the economic field by intelligent control, we have only to look at the past and present of the gipsy moth. A couple of weeks ago I was motoring along Cape Cod. Dead trees were standing everywhere in the woods. My host told me that these had been killed by the gipsy moth. Not only that, but for some years there were no leaves on any tree in all that neighborhood, and the caterpillars came down, when they had stripped the trees, to eat the grass and flowers. On a still day the woods were full of a sinister rustling—the munching of a million jaws, and rattle of the million pellets of undigested food continuously extruded by the destroying army. Hundreds of thousands of dollars a year were spent by the State in spraying and other curative measures: but with only meagre results. Eventually biology came to the rescue. Entomologists studied the gipsy moth in its original home and discovered just what natural enemies it had there. They imported these enemies—a beetle that devours the eggs, another, larger, which attacks the caterpillars, and a hymenopteran whose brood, deposited as eggs in the caterpillar, devours the growing animal from the interior.

These keep the gipsy moth in check, so that to-day the countryside is green again, and the moth, though not exterminated, is become only a minor annoyance. Without the meticulous knowledge of the ways and life-histories of a thousand and one apparently useless beetles and flies and moths, amassed often just for the sake of knowing, such control could never have been accomplished.

But to return to the other side of the picture. The discoveries of variability of resistance have in the last few years become linked up in the most interesting way with work in nutrition and work on the effects of light.

As every educated person now knows, it has recently been shown that certain substances which we call vitamins are necessary in our food if health is to be maintained. We can be given diet which is apparently ample in every way for all our requirements of repair and energy, but in the absence of vitamins we cannot utilize it. What exactly and chemically they may be we do not yet know; we know that they are necessary, and where they are to be found. Some years ago, it was apparently demonstrated that rickets, that scourge of slums, was what is called a deficiency disease—a disease due to lack of vitamins. Animals could be made to develop rickets by depriving them of one particular vitamin, and could be cured again by supplying the deficiency. Cod-liver oil was found especially potent in its curative properties; and, as a result of this discovery, cod-liver oil in shiploads has been used to set the undernourished population of Vienna literally on its legs again.

But investigation proceeded; and the story turned out not to be so simple as we had supposed. Of animals kept on a diet with a minimal quantity of the vitamin, those which were kept indoors in dark rooms and crowded cages would develop rickets, those kept outdoors in the light and

with opportunity for exercise would not. Exercise and especially sunlight could, it seemed, replace the vitamin.

On my way down here I visited the University of Wisconsin. There Professors Hart and Steenbock are carrying the matter a step further. They are finding that a great number of substances which normally are useless in preventing rickets can be made effective by a short exposure to sunlight or to artificial ultra-violet light. Their belief is that some inactive substance is activated, turned into the active vitamin itself, by the rays of light. Meanwhile workers in other lines have been exploring the possibilities of light. They have found that ultra-violet light, whether in the light of the sun or generated artificially in the laboratory, has the most remarkable effects. It heightens the natural resistance to infection, it alters the blood pressure, it tones the skin, it stimulates growth. Miraculous effects, particularly with children, are being obtained in hospitals all over the world with light treatment. Slum children, tuberculous, emaciated, pale, rickety, with ulcers and sores upon them, come for a month or two to such places as the Treloar Hospital in the country near London, and go back vigorous and healthy.

When to the radiant energy of light is added a cool temperature, as at high altitudes in the mountains, the effects are even more remarkable. This was first demonstrated by Rollier in Switzerland; and Professor Hill of London has explored some of the underlying physiology of the process.

Civilization is thus correcting its own mistakes. In its blind hurry it aggregated thousands after thousands of human beings in cities. To house them cheaply it erected tenements; to feed them simply it sent in canned food; to save trouble or money, it let a pall of smoke hang over

them; to save space, it cooped them up without sufficient room to stretch their limbs or play.

And in so doing it excluded the light of the sun from their life and the vitamins from their food, and thus stunted their growth and lowered their resistance to disease. Now the wheel comes full circle. We see what we have done; but there is a world of harm to undo.

The moral of all this is plain to see. We can do a great deal to ameliorate human suffering by getting rid of tangible enemies to health; but that is not enough. Remove all the living enemies to health in the world, all the germs, all the parasites, all the venomous creatures: and men will not necessarily be healthy. Health is a living, active principle which needs fostering on its own account. It is like a plant: it is not enough to keep the children from trampling on it and the goats from nibbling it down; it must have its own power of growth within it. And the necessities for active health come back to the simplest and most fundamental things—diet, bodily exercise, air and light, and mental interest. Body and mind must be used, the gifts of sun and wind not despised, and food and drink be properly regulated in quality and moderated in amount.

It all sounds so simple: but to be simple does not necessarily mean to be easy! At least, however, we are released from the false optimism of the germ-theory period, and reminded that healthy living, like all living worth the name, is an art. We can simplify the practice of it, but at the end we must bestir our individual selves to attain success. Medicine is still groping for the cause of cancer: but even with cancer it will probably be found that a rational life will do more to prevent it than any specific measures, in just the same way that cleanliness, good food, well-built houses and good sanitation have done quite as much to banish

smallpox, leprosy or plague as have vaccination, segregation, or the deliberate destruction of rats. In any case it is safe to prophesy that medicine will tend more and more to become preventive instead of curative—a tendency which will involve a radical change of status and outlook among the medical profession.

So far we have spoken of biology in relation to the health of the individual: now we have to discuss its bearing on the health of the race.

Two problems confront us, the one immediate and pressing, the other more complex and less instantly urgent. They are the problems of birth-control and of eugenics. Let me remind you at the outset of some elementary facts, of some of which I spoke in my first lecture. The continuity of the human race, like that of all organisms, is assured by a continuity of actual substance. The child is produced by the growth of a portion of living matter which once formed part of the parent. In all higher animals there is sexual reproduction—the child has two parents, and each contributes a living share. These contributions are cells, the *gametes* or marrying cells—the ovum or egg from the mother, the sperm from the father. The hereditary constitution is part of the gametes. It is that which determines the main lines of development; and it is given, irrevocably, at the moment of union of the two gametes and consequent origin of the new individual. To be sure, the environment also has its molding effect; but the effects of heredity are more deep-seated. Differences between people may thus be due to differences in their hereditary constitutions, or to differences in their surroundings. How potent may be the force of heredity to over-ride environment is most vividly seen when, as often happens, we find in one and the same family children of very diverse physique, intelligence, tem-

perament, and looks. In a sense, of course, the environment is all-powerful. Take away the whole fabric of civilization and place unlettered children to grow up on a desert island, and it will be centuries and tens of centuries before they could build up for themselves a civilization of their own, or think and act as we do. This only implies the obvious fact that environment and heredity are both essential, both what the scientist calls limiting factors. Modern man as we know him is impossible without a certain framework of environment; he is also impossible without a certain type of hereditary constitution. But within the bounds of one class, within one civilization, the environment is comparatively uniform. I am using the word environment in its widest sense, to include the framework of society, and the traditions which man has built up for himself—religions, philosophies, conventions, sciences—as well as the non-human environment of climate and physical surroundings; and the social and traditional environment is, over most of the globe, more potent than the natural. But within the bounds of any class, and, indeed, of the whole of a democratic civilization, heredity is of more importance than environment.

Now a child may have a good inheritance or a bad one. The fairy godmother of the old tales comes back to modern life as the chromosomes and the Mendelian factors or genes which they bear. There is to-day no more doubt that mental qualities are heritable than that brown hair or a hooked nose is heritable. Musical aptitude and mathematical talent in particular have been traced in their descent through member after member of a family, and there is no question but that general ability, intensity of emotion, and temperament, also follow the same laws in their hereditary transmission as have been worked out for more easily measurable

physical qualities. The simplicity of the relation, however, is masked by various facts. In the first place, it is highly improbable that a quality so complex as imaginative power or scientific ability depends upon a single Mendelian gene; apparently simple physical characters like stature or eye-color we are now finding to depend upon the coöperation of a large number of genes, and so it will be with mental qualities, too. But sexual reproduction works in such a way that at the origin of each new life there is a shuffling, a separation, and a new recombination of the hereditary factors of the parents. Only half the factors of either parent can find their way into the offspring, but the halving is accomplished differently each time. Thus new arrangements of the units occur. The units themselves, apart from occasional mutations, remain the same; but they appear in ever new constellations. Thus, in the present state of our knowledge, it is impossible even to try to predict the exact characters of an individual; although statistically we can make forecasts of extreme accuracy.

Much misconception exists as regards the number of gametes which come to maturity. In lower forms of life, there is an appalling waste of living material at reproduction. You remember Tennyson's lines about Nature—

> "So careful of the type she seems
> So careless of the single life";

and how the poet speaks of himself as

> "finding that of fifty seeds
> She often brings but one to bear."

But he was guilty of gross understatement! The oak will bring not one out of fifty, but one out of many hundred thousand seeds, to maturity. There are starfish which at

each act of reproduction liberate a population of eggs, each one capable of growth into a new individual, exceeding the human population of New York and London combined; and yet the race of starfish does not choke the earth.

In higher animals, the waste, especially on the female side, has been much reduced. The average woman only produces about four hundred ripe ova in the course of her life. On the male side, however, the wastage is even more beyond our comprehension. For each egg of the female starfish, the male will produce some million or so sperm, while even in a mammal such as man, for each sperm which successfully fertilizes an egg and becomes incorporated into a new life, many billions come to nothing.

And yet each sperm and each egg is alive; each contains packed within its microscopic body all the baggage which the human race needs on its journey through the generations; each is in a certain real sense as much a separate entity as the adult man or woman: so that, as Punnett put it years ago, the human race consists of four kinds of individuals—men, women, sperm, and ova.

With these preliminaries we can return to ask, what is the situation as regards birth-control? It is fairly plain. The regulation of the numbers of population, in some form or another, has been practiced by the great majority of the human race. As Professor Carr-Saunders has shown in his remarkable book on the Population Problem, every savage and primitive people of which we have any knowledge, almost every people of the early civilizations, and many peoples of the civilizations of to-day, deliberately regulate their numbers. Famine and wars are not and never have been sufficient. Either infanticide, or abortion, or various restrictions upon or regulations of marriage, have been practiced, with the effect of preventing or slowing the

natural increase of population. The quick growth of population which has followed every great rise in the level of civilization is the exception, not the rule; and the great and rapid increase which has obtained in Europe and North America since about 1800 is probably unique. It has been due to three main causes: first, the alteration in the methods of production which is summed up in the word Industrialism; secondly, the injunctions of the Christian churches in general and the Roman Catholic Church in particular; and thirdly, the great development of curative and preventive medicine. The precepts of the Church have always been similar; but in the past, war, famine, and disease have slowed if not stopped the full natural increase. Industrialism has meant that a greater density of population can actually be supported by a given area than was previously possible; and sanitation and medicine have seen to it that a much greater proportion of the natural increase of children shall survive and fill the vacant spaces.

But the vacancy has diminished; and industrialism has brought its own errors and tragedies. A continuation of the rapid increase of population did not seem so desirable in 1900, or even in 1875, as in the early days of expansion. Malthus was the first warning voice; and though his calculations and ideas were often wrong in detail, his fundamental principle remains sound. Various methods of birth-control began to be discussed between 1840 and 1870; but it was not until about 1870 or 1880 that technological advances put the matter on a really practical footing. From that day to this the practice has increased. Sir William Beveridge has recently analysed all the available figures, and finds no escape from the conclusion that the drop in the birth-rate which started at nearly the same moment in all white countries (except—a significant exception—those which are

predominantly Roman Catholic) owes its existence almost entirely to the improved practicability of birth-control. The same authority—than whom there is no greater living on the subject—prophesies that the population of Great Britain will, within the next century, cease to grow, reaching a stable phase like that seen in France to-day; and Raymond Pearl foresees a like consummation, though arriving a few decades later, for the United States.

It only remains to be added that while the practice itself appears to have become increasingly prevalent, the official attitude of the State towards it has never been favorable, while many organizations, especially "patriotic" and religious bodies, have bitterly opposed it.

The situation as it stands to-day is absurd. Here is a biological invention which if consistently and generally practiced must revolutionize society. At one stride it makes it possible for man to regulate his numbers and to enter once more upon a stable period in regard to population, but without reverting to any barbarous practices such as infanticide, and without going through the cruel ordeals of plague and famine. The practice grows obscurely but steadily; yet there is no overwhelming mass of opinion either to aid or to check it.

The chief trouble has been, and still is, that the matter is not discussed in any open spirit. Our first duty is to see what is at stake and then make up our minds without prejudice.

It is clear that population cannot continue to grow indefinitely. Already trouble, both international and domestic, is being caused in some countries by the need for population's overflow; not only that, but we are continually tumbling over ourselves in the attempt to catch up with the social problems which call for adjustment—only to find,

when we seem to have neared achievement, that the growth of population has brought a whole new crop of evils for our goodwill to tackle. On the personal side, only those who have been among the poor in big cities know how cruel the withholding of birth-control information can be. I have a friend in London who devotes a good deal of time to one of the voluntary birth-control clinics there: she tells me stories of the women who come there, working women on the lowest wages, coming diffidently and shyly, usually with their husbands' approval, to seek knowledge. Ten years married, seven children, five dead in infancy; four years married, one baby and two miscarriages; chronic ill-health, too much work to do, too many mouths to feed, another on the way—that is how the poor too often live. Mr. Wells wrote none too strongly of a recent refusal of the British Government to allow advice on birth-control to be given like any other medical advice in state-aided clinics. The refusal of Authority to allow men and women knowledge on the most fundamental facts and processes of existence is, he said, a tyranny which contradicts all the ideas underlying our civilization.

The further consequences are twofold. In the first place, quantity of births is always associated with quantity of deaths. In general, large families mourn more baby deaths: they involve a massacre of the innocents.

Further, from the standpoint of the community, quantity is not nearly so desirable as quality. Militarism and big business in its cruder aspects alone can want numbers as such—cannon-fodder or machine-fodder. Society wants men, not mere pawns in the game.

But that is not all: as matters stand at present, birth-control is actually practiced, but preponderantly by certain sections of the community and not by the others. In all

civilized countries the birth-rate of the upper classes—aristocracy, professional people, business men, and tradespeople, is now much lower than that of the laboring classes. This is a new phenomenon; in earlier times the birth-rate was similar from top to bottom of society; the change became noticeable in the latter part of the last century, and is without doubt chiefly (though doubtless not wholly) attributable to deliberate birth-control.

At present twenty per cent. of the population in Great Britain gives rise to twenty-five per cent. of the next generation; and the average of this twenty per cent. is neither physically nor mentally as good as that of the other eighty per cent. We are thus confronted with a process which is retrograde in its effects—dysgenic instead of eugenic.

Before we can talk about eugenics, we must prevent this unequal multiplication. There is no prospect whatever of inducing the upper classes to abandon birth-control; our only hope is to equalize the increase throughout society by making birth-control universal and starting afresh on the new level.

There is of course no sacred right of a child to be born any more than there is a definite moment when it acquires a soul, immortal or otherwise. But it is remarkable how often the prejudices on such intimately biological matters as birth-control, when not caused by mere ignorance of the facts of nature, are due to this desire to force natural phenomena into unnatural categories of the human imagination, to insert the cuckoo's eggs of Absolute Rights and Values into the simple nests of natural reality.

The whole trend of evolution from lower to higher has been towards diminishing the number of offspring, but increasing the parental care, both before and after birth, which is bestowed on them. I think I am right in saying

that biologists are almost unanimous in demanding a rational birth-control as one condition of social advance.

Closely linked with this subject, as will at once be seen, is Eugenics. A rational birth-control is the necessary prelude to a rational eugenics. In the course of evolution the blind forces of natural selection have generated, in man, conscious knowledge and will, and to that conscious knowledge and will has been entrusted the task of progress, up till then blindly and painfully achieved.

Blind forces still operate in us, as we all know. The driving springs of instinct, the unrecognized power of repressed desires or fears, the consequences of a particular economic arrangement, undreamed of at its inception but working themselves out, the accidental but inevitable results of some form of social organization, the automatic urge of competition—these chivy and drive us, individuals and societies alike, whether we wish it or no.

On the whole, they seem to push us onwards, in the line of progress. But what is quite clear is that alone they cannot push us beyond a certain point. It would be more accurate to say that they cannot touch us at all except on certain levels, and these levels not the highest on which our existence moves. Our highest activities must be controlled and illuminated by consciousness; the upper reaches of our existence, in art, in morals, in intellect, those levels on which man is truly a man and not an animal—these are all unattainable except by the use of conscious reason, conscious will, or conscious emotion.

Thus, any true advance, any advance in quality of life, can only operate through consciousness. Through consciousness we become the trustees of the evolutionary process. This is the simple but glorious truth underlying eugenics.

Eugenics can become actual in a number of ways. We can improve the level of achievement by improving conditions and social organization. This is the gospel of ninety-nine out of every hundred educational and philanthropic bodies. But it is by itself an incomplete and even dangerous programme. It cannot raise the potentialities of achievement, as these potentialities were raised in the passage from reptile to mammal, from man's ancestor to man; and it cannot prevent degeneration of the stock.

To take the latter problem first, we know now, first, that harmful recessive genes are carried in the stock of any sexually-reproducing organism, perfectly harmless and without effect—so long as two similar ones are not dealt out to one individual after the shuffling that accompanies reproduction. It is on this account, and this account only, that the marriage of near relatives may produce ill effects. Inbreeding is not in itself bad; but, if there is in the stock any hereditary taint, due to recessive Mendelian factors, inbreeding will bring it to the light and to pernicious activity.

We also know that mutation, or actual change of hereditary factors, is slowly but continually occurring. We also know that the majority of such mutations are harmful—a result which we might have prophesied on the simple theoretical principle that it is easier to damage a complex bit of machinery, or throw it out of gear, than to improve it.

In nature, natural selection will operate against the poor combinations of existing characters, as well as the poor new-mutated characters, and they will thus tend to die out as soon as born. But the whole trend of human civilization is towards their preservation. The very existence of society means that natural selection operates more directly upon the social organism as a unit, less upon the single individuals of which it is composed. Philanthropy

has of late years conspired with modern medicine and modern sanitation to preserve ever-increasing numbers of individuals who would in less civilized times have died off in youth or infancy. There is a very real danger that the average quality of the population may be changed for the worse by the survival of the unfit—a danger that is made more acute by the fact, commented on earlier, that on the whole the undesirables multiply faster than the desirables. All the evidence, it is true, goes to show that the actual physique of the people of Western Europe, as measured by stature, by expectation of life, has increased during the historic period. But this improvement appears definitely to represent only a fuller realization of the innate potentialities that already existed and has been made possible by an improvement in the conditions of life. It is being now counterbalanced by the lowering of the average standard of potentiality. Especially serious is the low standard in the qualities of the mind.

The greatest shock of the war to far-sighted people was the revelation of the United States Army Intelligence tests. Even when various necessary discounts have been made, they showed that the intellectual capacity of the average American man was distinctly low. I have no doubt that similar tests in any other country would reveal a similar state of affairs.

The long and the short of it is that we have not yet thought seriously of the future of the race. We spend endless time and money in improving the breed of horses or sheep, we pay fancy prices for prize dogs or pedigree bulls; but we let the breeding of men shift for itself, until we are becoming a scrub herd of mongrels. The only practical thing that is ever done in connection with race is to offer prizes and bonuses for large families: by this

means we may encourage quantity, but often at the expense of quality. We neither attempt to improve the stock, nor even to prevent it from degenerating.

Moreover, there are no essential difficulties in the way of our second ideal, the prevention of racial degeneracy. The collection of statistics and the improvements in physical and mental testing are giving us reliable information as to the inheritance of all kinds of defects. Men like Davenport and Goddard have shown clearly that true feeblemindedness is an inherited character, inherited often in the simplest Mendelian fashion; the work of places like the Psychopathic Laboratory of the City of Chicago is proving not only that emotional instability and disorder is at the root of a great proportion of crimes of violence, but that it runs in families in the most striking way. Morons breed morons, and neurotics of criminal tendencies bring others like themselves into the world; and we let them do it. The situation is aggravated when we find that on the whole these undesirable types have a higher fertility than the rest of the population, so that their relative numbers are tending to increase.

We have to make up our minds to a new step in human history: to the conscious control of reproduction. This is being done individually with birth-control: it must be done socially by what we might call mating-control. When we know that men or women are not only the embodiments but the bearers of hereditary taint and defect, we have no more right to allow them to reproduce than to allow a child with scarlet fever to be visited by all his school-friends. We are told that this infringes the sacred rights of the individual and prejudices the idea of personal liberty. Such utterances are but another example of the unfortunate tendency, apparently inherent in the primitive human mind, of demand-

ing and pretending to find absolute sanctions for ideas which are not in any sense absolute. If we talk of the divine and inalienable right of personal liberty, we are talking bunkum, and trying to transmute a practical idealism into terms of an abstract theology. Everyone knows, directly they begin to think about the matter, that what we call liberty is a compromise between the claims of the individual and those of the community, a compromise between abstract justice, selfish egotism, practical give-and-take, and social expediency. Before it was known that various diseases were infectious, the liberty of sufferers from these diseases was not curtailed; but immediately it was recognized that this liberty involved the infection of others, it was also recognized that the community had a perfect right to curtail liberty in that particular respect. In other words, the degree of liberty which the individual can possibly expect is and must be conditioned by what we know and think of the effects of that liberty upon others.

Undesirables can be prevented from reproducing their kind by permanent segregation. The advance of scientific methods has made it possible to secure the same result in a more humane and less expensive fashion; they can be sterilized by an operation which in the male at least is exceedingly simple. A beginning has been made in various lands. This country and Switzerland lead the way; but the numbers of such operations are as yet infinitesimal. What we want is a clear recognition that racial health is of equal importance with individual and social health; once this is gained, action will follow from the pressure of opinion. When it is realized that the defective germ-plasm, which the nations of the world pass on in the stream of life from one generation to the next, is certainly not less, and perhaps more, potent than bad physical surroundings, poor

upbringing, and defective schooling in filling our jails and hospitals, in causing social problems that need never exist, in calling for vast expense in mere cash, in diminishing the efficiency and happiness of the world in a wholly unnecessary way—once all this is realized, we shall not be so ready to allow a fancied right of a single person to inflict lasting injustice to the community The curse of modern democracy is sentimentalism, which is to morals what bad taste is to art. It mistakes shoddy for the genuine article, and erects false values in place of true.

Bad taste often over-emphasizes the obvious but trivial at the expense of the essential—have we not just emerged from an age of over-decoration and under-planning? Sentimentality does the same. Bad taste has no sense of the rational congruity of some things, the hopeless incongruity of others—it does not think. I once saw a drawing-room "ornament" in the shape of a copy of the Venus of Milo with a clock let into the stomach! Sentimentality suffers from the same refusal to allow reason to break down water-tight compartments or to allow it a hand in the shaping of an organic whole. Sentimentality clamored to hang the Kaiser as a solution of all after-the-war international problems. Sentimentality gives money to beggars without thinking whether an order of society which produces beggars may perhaps need changing. And sentimentality juicily rejoices (as I saw in the newspaper not long ago) over the "romance" of a marriage between two congenital deaf-mutes—without once reflecting on the crop that it was raising for the future.

We do not hesitate to weed our gardens. For God's sake, why do we hesitate to weed the garden of humanity?

If we once made up our mind to it, this negative, weeding kind of eugenics could be easily practiced. It must be

confessed, however, that positive eugenics, or the raising of the upper level, is not so easy. In the first place, though we can be perfectly sure that the same general principles apply to human inheritance as to inheritance in other animals, we know very little about the details, and cannot solve any of the more difficult problems so long as we cannot control human matings for the purpose: and this, even if it were desirable, is certainly not at present practicable. In the second place, any selection which we could practice, in any state of society at all resembling the present, would produce its results extremely slowly and inefficiently. Let us take an example from domestic animals. In fowls, it is desirable to secure high winter egg-production. This property appears to depend upon a number of Mendelian factors, hard to disentangle from each other; the easiest way to go about obtaining it would appear to be by simple selection. But the selection can be of two kinds—mass selection, or individual selection. In mass selection, all those birds with more than a certain record of production are taken and used *en masse* as parents of the next generation. With individual selection, on the other hand, single good performers are taken and bred from separately. When this latter method is adopted, it is found that some of the original high layers owed their good performance to some accident of diet or other extraneous circumstance, and not to the inherent qualities of their germ-plasms. Their offspring were only average or even poor performers. As a result of an actual experiment it was found that the effect produced by generations of mass selection was negligible, while individual selection, by enabling the impermanent and accidental effects of environment to be weeded out, at once and markedly and permanently raised the level. There was one relevant difference between this

flock and human society; with the hens, the whole breed had for some time been subjected to some form of selection for good productivity, so that the really poor strains had already been weeded out. In human society, most of the qualities which we prize the highest are not only complex, doubtless depending on numerous hereditary factors, but easily modified by environment and education. We all know how temperament and intelligence, for all that the basis for their potentialities is given in the germ-plasm, are profoundly responsive to training and surroundings. But in human society as at present organized, mass selection would be the only possible method to adopt. To attempt to reproduce the race wholly from a few thousand, even a few ten thousand, individuals, would for the present be unthinkable. We can do something, but very little, and that little only by running counter to some of the most cherished sentiments of our democratic age. We have got to stop pretending that comfortable mediocrity is our ideal, and that the average man is the god to whom the rest of the world must bring their sacrifices.

Already the conflict is making itself practically felt. With the growing demand for higher education, the consequent growing burden upon the academic profession, with the shift of emphasis from research to teaching, and the consequent growing cost to the state, the question is being asked (especially in this country, where the problem is perhaps most acute) whether the fact that a young man or woman desires a higher education is in itself a sufficient reason for allowing him or her to enter college, even if that college be a state institution in a democratic country. A noted educationalist at one of your most noted state universities told me the other day that he had raised that very point; and that in consequence the president had asked

to see him and had very pleasantly but quite firmly told him that this question should not be asked in public by a professor of a state institution. In the present state of public opinion that may be so. But the question will be asked outside, and the problem will not only remain but will grow more acute.

The younger Haldane has dealt with the question in its eugenic aspect in his pithy and amusing booklet "Dædalus". He does not believe that any substantial improvement of the human race could be made, not merely under our present type of social system, but with our present technical methods. He points out, however, that tissue-culture is in its infancy. Half a century ago, the idea of growing bits of animals outside the body would have seemed chimerical. To-day it is an every-day method. Even the tissues of old animals can be made to grow by the use of proper media, and cells from a chick embryo have been kept alive and multiplying for a time much greater than the maximum life of a fowl. What is to prevent us from devising methods which will not only enable us to grow reproductive cells in tissue-culture, but also to bring up the embryo outside instead of inside the body, substituting the incubator for the womb, and an artificial nutrient medium for the maternal blood? Such an idea, like all ideas which touch our feelings, seems at first not only impossible but impious. But Prometheus was thought impious in the past; and the most respectable evolutionist or practiser of birth-control is called impious to-day, by the perfectly sincere occupants of a thousand pulpits.

Whether impious or no, the possibility of such a technique would bring with it the possibility not merely of evolutionary advance for man, but of rapidity in that advance. A few hundred individuals could be chosen as the procreators

of a whole generation, and individual selection and conscious control would become practicable. Whether the mass of the population would consent to sacrifice direct parenthood for the sake of the race, and be content with adopted children or even a communistic nursery—that is another matter. But if ever such technique comes into being, it will bring with it a conflict on this, the most momentous question which humanity will ever have had to face.

Another matter connected with eugenics is the control of sex. Here, in spite of the mystery with which the subject has in the past been surrounded, all now seems plain sailing. The mystery is in its essentials no longer a mystery. We have been able to see in the diversity of plant and animal forms almost every conceivable stage of the evolution of sex; we understand in broad outline its *raison d'être*, its biological function; and we know the mechanism of its determination in higher animals.

As I pointed out in a previous lecture, sex is determined, in man as in all other mammals, by the sperm of the male. There are two kinds of sperm, one larger and one smaller; the larger is female-determining, the smaller is male-determining. Artificial fertilization is perfectly practicable; it was successfully employed in mammals by the Abbé Spallanzani in the eighteenth century. It remains now only to separate the two classes of sperm according to their size, and sex-control would be an accomplished fact. I cannot believe that this separation would present great technical difficulties—certainly none as great as were involved in the construction of an efficient phonograph, or a modern aëroplane. Yet these inventions were perfected in a few decades. I will venture to prophesy that in the matter of sex-control it will be only a few decades before the invention reaches the practical stage.

Then, as with all inventions, the question arises as to what use we shall make of it. With domestic animals, doubtless, the method will have immediate and important application. What a lightening of labor and anxiety to the stock-breeder or the fancier! But how will it be with man? Would it ever be desirable to risk upsetting the proportion of the sexes by allowing individual parents a free hand in choosing the sex of their children? I am inclined to think not, and to believe that the state should assume complete powers in regard to the question, allowing the method to be employed only in special cases.

But in special cases, what happiness it might bring! Who does not know families of six boys, or eight girls, in which the parents are pining for a child of opposite sex?

In any event, here as ever, the advance of knowledge brings humanity face to face with the need of new decisions.

Another allied problem which calls aloud for solution is the problem of race. You in this country know better than most peoples the difficulties attending the coexistence in one country of widely-divergent racial types. But the same problem in one form or another is to be found all over the world. In India, in South Africa, in South America, it is urgent: it may at any time become urgent in China, Japan, Australia, Equatorial or Northern Africa. Professor Gregory gave a thought-provoking study of the subject in his presidential address to his section at the British Association this summer. He came to the conclusion, with which I think most people would agree, that the best way of dealing with the problem of race is to prevent it from ever becoming a problem. Where practicable, nations should aim at homogeneity of race. Note that by race, here, Dr. Gregory implies only the broadest racial divisions. He is thinking of whites, blacks and yellows.

True that in many parts of the earth there has been mixture between these three main types; but that in no wise prevents the original dissimilarities from being any less important. In this, biology supports him. The so-called racial differences within one of these main divisions are few and of less importance. The average man too often makes the old mistake of confusing nationality with race. There is a British nation and a French nation; but no British or French race. The distinction is at once clear when we look at this country. The American nation is a very important reality, but God help the man who begins to try to define what he means by the American race!

America is naturally destined to expand for a longer period than Europe; but even you here in Texas, living in a period of the most rapid change and progress, must accustom yourselves to thinking of a stability of population as not only the inevitable, but also the desirable, last state of your country. Progress will then be measured not by counting heads, but by the advances man makes in his conquest of nature and in the discipline of himself—in the control of external forces and in the art of living. To achieve this fully, it is necessary to have a coherent population; that does not mean a uniform population, but one in which there can be free mingling of the different types, no alien elements or unabsorbed masses of people, and no large proportion of disharmonic combinations.

Viewed from this aspect, your immigration policy seems biologically wise; in a hundred years our descendants will probably see a fully unified white American population, with consequent dying out of the wild fears about foreigners and Bolsheviks which have swept this country since the war more violently than any other in the world. As Professor Pearl points out, the mere restriction of immigration is

probably more important for you than the proportions of the stocks which you allow in.

I say the white population. Of the colored problem I will not speak, because its solution in this country does not yet seem to be even in sight. In South Africa I hope we shall try segregation, the delimiting of areas for blacks and other areas for whites. In South America intermarriage and the creation of a mixed white-Indian-negro stock has been practiced. Neither of these seems practicable in this country, and time alone will show what can be done.

Before closing, I must try to touch on a few questions in which biology seems to throw light upon sociology.

If we study evolutionary progress, we find that the higher animals are all highly unified, all characterized by the possession of a centralized and dominant organ, through which the behavior of the whole is controlled. This organ is the brain; and not only is it the organ of control, it is also the organ of consciousness. Increase of intensity of mental power is also a part of progress. It culminates in the self-consciousness of man. So was generated the possibility of life on a new level, with new values; and the greatest men direct their activities preponderantly on this new level, living in a world of intellectual, moral or æsthetic values. From another angle, we may say that increase of intensity of mental process appears to be a necessary accompaniment of increased biological progress and increased efficiency of control.

Is there any application of this to the problems of society? I believe that there is, although many thinkers have denied that any profitable parallel can be drawn between the organism and society. It is perfectly true that there are vast and important differences. For instance, it is clear, both to immediate feeling and to careful analysis,

that the individual is of higher essential value than society: in other words, that, although society must be preserved when it is threatened, because organized society is necessary to civilized existence, yet in the long run society exists for the individual, not the individual for society. Yet only by an efficient carrying on of the business of society as society, as a unity or individuality of a higher grade than man, can individual man realize his potentialities to the full. The solution lies in man's plastic mind; he can turn at will from an independent individual to a mere cog in the machinery of society and back again. He can thus, for part of his time, devote himself to the ends of the social organism, and then reap the harvest in his capacity as an individual organism. In so far as men and women are devoting themselves to the workings of society, just so far is the society which they compose a true organism; and the laws which we find applying to other organisms will apply to it.[1]

Not only is there a dominant controlling organ, in the shape of the brain, in adult higher animals, there are dominant regions in development. As I pointed out in my first lecture, the process of differentiation, the development of something out of nothing in the developing embryo or the regenerating animal, appears to be dependent on the presence of a region of great activity. How great activity of one tissue stimulates other more passive tissues to the activity of differentiation, we do not know; but it appears to be a fact.

Both these phenomena seem to have their counterparts in the working of human society. In so far as society acts as a single organism, it must have an efficient controlling

[1] The problem is, of course, complicated by the fact that the individual human being is a higher type of individual than society, the aggregate of which he forms part—the reverse of what obtains in most organisms. What I have stated is true, but only within the limits mentioned.

organ. This is most clearly seen in time of war, but is just as much present, though not in so clear-cut a fashion, in peace as well. Public opinion, the press, the legislature and the executive administration, universities, bodies like national research councils and churches—these together (though with considerable friction) operate as the brain of society. And as regards differentiation, which here means properly directed change, new intellectual or social evolution, it is an obvious rule that it is brought about by exceptionally active minds which act like a ferment and set others to thinking and acting in new ways.

I think it would be well if we asked ourselves whether our present brand of democracy is calculated to give us the best organs of social control and differentiation.

The advantage of democracy is the raising of the condition of the mass of the people to a good average. The curse is the tendency to pull down what is above the average to the level of the average's mediocrity.

A democracy of material opportunity freely surrendering itself to the guidance of an aristocracy of thought—that seems to me to sum up pretty closely the biological ideal for society. But we are far from it yet.

There are scores of other ways in which biology can now, or will eventually, affect practical life. The science of genetics, an infant but an infant Hercules, is bound in time to change the practices of stock-breeders; the present pedigree system has its many advantages, but it has its genetic and economic absurdities, in the emphasis on an old aristocratic pride of ancestry quâ ancestry, irrespective of scientific analysis, and in the fantastic prices given for pedigree prize-winners.

Greater knowledge of physiology will doubtless enable us to modify the processes of our bodies more in accordance

with our wishes—to stimulate our faculties when we need high-tension work, but without evil after-effects; to relax them without the use of harmful soporifics.

It seems clear that temperament, even more important than pure intellect in achieving success, is largely an affair of the balance of the various glands of internal secretion—thyroid, pituitary, reproductive, adrenal and the rest. It may well be that the applied physiology of the future will discover how to modify temperament. Many men of sedentary life came back from the war with altered temperaments. Probably, to use Cannon's phrase, they had "discovered their adrenals"—the violent activities into which they were forced made demands upon the adrenals and other glands which their previous life had never done: the glands responded by increase of function, and a new equilibrium was set up which they preferred to the old; and consciously or unconsciously they refused to let it fade out when they returned, but adjusted their mode of life so that it was continued on a different plane. We are sure to discover more and more of the means of playing on this complex system within us and eliciting from it the vital harmonies which we desire.

We are likely to be able to apply plant breeding to create new forms of life which will work for us in unsuspected ways. As primitive man learned to use yeasts to make his alcohol, bacteria to manufacture vinegar and cheese, scientific man is certain to find ways in which he can build living factories, as well as dead, to supply his wants and luxuries.

But I must close. Let me remind you that while pure science will make discoveries so long as she exists, while technology will apply those discoveries so long as profit is to be made out of their application, it is in the long run the average man and woman who decide *how* that application

shall be made. Whether the discoveries of science will in the ultimate event be beneficial, as those of us trust who believe in progress, or whether they are leading the human race to destruction, as many sincere and many far-sighted men assert—that will be decided by the use to which the human race decides to put them. In themselves, apart from their intense personal value to their discoverers, and to others on the plane of pure intellect, they are neutral, like any other tool.

Let me also remind you that humanity is always mistrustful of any radical change, and especially so in any field which touches their feelings and their instincts. All large biological discoveries are bound to affect human feelings and instincts; and so, as Haldane points out, they will always by a great proportion of mankind be greeted as impious, immoral, or indecent. Look at the myth of Prometheus; remember the edicts against the practice of dissection by the early anatomists; remember the storm of obloquy that broke on Darwin's head; look round to-day and see what pious curses are being launched at birth-control and eugenics; and try to apply the needful psychological corrective to any immediate reaction you yourselves may feel towards any new project based on biological knowledge.

Recall that, as Mr. Trotter somewhere puts it, when we find ourselves holding an opinion with particular tenacity, that is probably a sign that we are holding it on irrational grounds; and remember that now in the fullness of time, the cosmic forces by which we were generated have made us the trustees of progress, and entrusted to our conscious free-will the future course of evolution.

III

PHILOSOPHICAL BIOLOGY: SCIENCE DESTRUCTIVE AND CONSTRUCTIVE

EVERY man has a philosophy of life. The philosophy of some folks is meagre enough; others keep the different aspects of theirs in watertight compartments. The great prophet, poet or teacher is he who can break down these compartments, give free play to the floods of actuality that pour in on every side, and yet not (like lesser men) be overwhelmed in the turmoil. He will take these violent but vital streams, combine their flow, use their full head of water for power, distribute them in peaceful runlets for the irrigation of new fields of life or old fields grown barren through the drying of the old springs. For let us not forget the world never stands still; to each generation the old problems come in new forms, with new problems on their heels. Bergson had the poet's insight in his vision of evolution as a creative thing. The new, the not-to-be-prophesied is constantly coming into being, does continuously arise from the old and the familiar. That is true not merely for the slow workings of animal evolution; much more is it true for the rapid changes of human civilization.

In this last century of human years, great and bewildering changes have been made both in man's understanding of himself and external nature, and in the material basis of his life—greater and more bewildering than in any other century of which we have record. These changes demand a new outlook and a new philosophy; and it is of

the contribution of biology to this new outlook that I wish here to speak.

In the first place, there is the realization of change itself, of the fact that society, like other organisms, must change if it is not to stagnate. There are organisms, like the lamp-shell Lingula, which have not changed for ten million years; but such are extremely rare. The law for the vast majority of species is change. That is especially true for those of generalized plastic nature; and man is preëminent, thanks to the construction of his brain, in plasticity.

There seems for man, as for most organisms, to be no escape from one of two alternatives. Either he must be going somewhere, or he must be like the old darkey in the story, who when asked where he was going, said, "Ain't going nowheres, I'se been gone where I'm gwine to". (One knows both individuals and nations who seem to have already gone where they were going to!)

The fact that the world never stands still is, to be sure, a chestnut of experience; but none the less important for that. Very often reason's contribution to a problem lies in providing an intelligible basis for some dimly-perceived familiar truth, in making its boundaries clearer and in seeing precisely how it operates. Biology does this for our general notion that the world does not stand still.

The discovery of the fact of evolution made change in the law of the organic world; and from a study of evolution we are enabled to say something as to the meaning of change for life.

By this we are shaken out of any conceit we might have that this is the best of all possible worlds, and made to see that, as I said yesterday, we are become the trustees of evolutionary progress; and that any state of the world in

which men and women are so far, as they are in the present, from realizing more fully the possibilities that are in them is very far from the end of its evolutionary course. There are actually people who hold up the existing order of society as divinely ordained and therefore presumably ideal. Such an attitude is, presumably, in most cases, the mere rationalization of a fear of change, but it is nevertheless pernicious.

The real problem is to strike the balance between stability and change—to make change itself regular. This has its practical bearings. Mr. Trotter in his book on the "Herd Instinct" has pointed out that one real classification of human types is into the stable-minded and the unstable-minded: that the latter are those who produce most of the great discoverers and reformers, the former most of the administrators and business men. Further, that the greater the innovators and reformers, the more are they usually attacked and reviled during their lifetime; and that the chief practical power and the bulk of wealth are in the hands of the stable-minded.

Our problem is to encourage the unstable-minded to make their discoveries and point the way to their reforms without letting them pull the whole fabric about their own and other people's ears; and this calls for a toleration that is even at present rare.

Apropos of this toleration, let me quote a passage I recently came across in Bernard Shaw's preface to St. Joan, since it is relevant to much of my later argument: under the section-heading, "The Law of Change is the Law of God", we read, "In short, though all society is founded on intolerance, all improvement is founded on tolerance, or the recognition of the fact that the law of evolution is Ibsen's law of change. And as the law of God in any sense of the word which can now command a faith proof against

science is a law of evolution, it follows that the law of God is a law of change, and that when the churches set themselves against change, as such, they are setting themselves against the law of God."

The greatest of the last century's changes lies in the new outlook on nature and man's relation to nature—in other words, in the theology of his religion, since religion is the response of human personality to the outer universe of experience, and theology is our attempt to give an intellectual statement of that relation, and build a rational basis for our beliefs.

There have been in the past two main phases through which man has passed in regard to this question: the period of magic, fetichism, and primitive animism, and the period of theism.

In the first period, whch must have started as soon as man was truly man, and began to try his reasoning powers, magic appears to have been the guiding principle of his existence.

What is magic? Anthropology studies the habits of every primitive people, and compares them with the curious survivals found in the highest civilizations. For want of a better term, the anthropologist uses magic to denote a certain set of practices which he finds in use. To be sure, they appear in a bewildering multiplicity of form, but analysis shows that all issue from a common cause—which in its turn is a particular theory of the nature of things.

Magic in its first, or fetichistic development, consists in ascribing supernatural attributes to physical objects such as stones or skulls or the skins of animals—in endowing them with a spirit-life and a share of the power which primitive man felt and feared moving in the world about him. Psychologically, the operation seems to be this.

An object arouses emotion; the primitive mind, not yet arrived at full distinction between subject and object, ascribes to the object some of the spiritual life which was manifested in the emotion. We too often do something very like this, and not only in our childhood.

Secondly, it implies the belief that by symbolic and ritual practice the powers of nature can be forced or propitiated to the fulfillment of human desires.

Both these beliefs long survived their first crude manifestations, and, with the necessary modifications, overlapped into the theistic period.

In this stage, further, men appear to have made no clear distinction between matter and spirit; they projected their own emotions into the objects which happened to arouse emotion. Religion of this type is an external thing like a patent medicine—it is, indeed, only a spiritual patent medicine. The great reform made by the Hebrew prophets was in urging the uselessness and stupidity of such a religion.

Gradually, it would seem, the Magic theory was found to be insufficient. Objects themselves came to be regarded as lifeless and passive; the spirit and the power that man felt in his confrontation of the world was taken out of objects and placed behind them, on a new plane. So was called into existence a world of spiritual beings, whose wills were supposed to control the actions of brute matter, of beasts, and of men.

This step was of profound importance, since it meant the severance of the bond in human belief between matter and arbitrary will. Two effects inevitably followed—slowly, and with pain and effort, but inevitably. On the one hand, Science was born. Matter itself became for the first time truly material. Up till then, it had been regarded as itself the seat of supernatural powers, incalculable,

irresponsible, illimitable; thus thought of as holy and mysterious, it was shielded by the powerful barriers of human emotion, by fear and longing and adoration, from any cold and dispassionate scrutiny.

But with the transfer of this supernatural power to separate supernatural beings, cold and dispassionate scrutiny of matter was no longer sacrilegious. Thus began the process which first emerged from its chrysalis in ancient Greece, as the scientific study of nature, and which in the last few centuries has trained its wings to ever greater and more astounding flights.

But as human reason worked on matter, so it could not help working on the powers which it perceived behind matter. As matter became better known, more controllable, so the spiritual beings who were thought to direct its activities were thought to be less capricious, more human, fewer in number. As human thought became more conscious of itself, as justice and pity, reason and purpose came to have more part in determining action, so, too, the nature of the imagined spiritual beings changed, and changed in the same direction.

Look at the gods of any advanced polytheistic people, such as the ancient Egyptians or Greeks. They are easily seen to be of compound nature. In part they are a deification of the powers with which the people are perpetually striving, a projection of the idea of human personality into the forces of nature; and for the rest they are a wish-fulfillment, a deification of human ideals—ideals given the victory, wishes made to come true by being given life among the gods.

Later there came a gradual unification of our ideas concerning matter. Different kinds of matter were seen to change one into the other, different kinds of energy to be

transmutable. The conception of a uniformity of nature underlying all material phenomena came into being.

So in respect of our ideas of spirit. If all the diversity of material fact were the manifestation of a single matter, then the diverse powers seen operating through matter must be manifestations of a single spiritual being. Then, too, the unity of mind was better realized, and at the same time the units of human society enlarged. And so the little gods died or merged in new and greater—the individual fetich, the family Lares and Penates, the tribal gods like early Jehovah, the gods of place like the Roman Termini, the gods of special time or season like Adonis, of a trade like Mercury, or of one aspect of the human mind, like Pallas Athene—the splendor of all these faded, and their life was sucked out of them—into beings of greater splendor and fuller life.

Finally, in due course of time, both scientific and religious thought came to the terminus of their advance, a bound beyond which no further progress was possible without a change of fundamental idea. Science has brought us to the final uniformity of natural law, the unity of all matter and all energy: religion has brought us to the most thoroughgoing monotheism, in which not only is a single spiritual being supposed to be behind all material happenings, but all logical consequences of ascribing personality to such a being are worked out to their conclusion. And the two systems in their simple and unmodified forms are incompatible.

We stand now at the threshold of a new phase of human outlook on nature; science seemed to have brought us to a locked door, but now science herself is forging the key to that door. Let us see a little more clearly how matters stand. Physics and chemistry, as was natural, took the first

great step. Both matter and energy were found to be indestructible, and every form of either to be interchangeable with other forms. The last twenty-five years' work in physics has put the final story on the building. Matter is not only indestructible, but all of it is literally one; as all the millions of different substances are built up of a few dozen elements, so these elements are built up of units of the one pre-elemental stuff. The different elements represent essentially but so many different numerical arrangements of identical units, the electrons; and these electrons, though the basis of matter, are the basis of energy, too. And so all material phenomena come back to arrangement and movement of the eternal army of electrons. As corollary of this, scientific uniformitarianism and determinism is justified and enthroned. In the realm of matter, there is no longer room for any miracle, save for the eternal miracle of existence itself.

Then comes biology. With one gesture she links life with not-life, showing that the same matter and the same energy is in both, and in both works in the same way. With another she gives us evolution, thus linking all life in one, and further posing the question of mind's relation with life, and so with matter.

Evolution and physiology, together, extend over the whole field of life the operation of the same natural laws which physics and chemistry found for dead matter. That is not to say that no further natural laws exist in life, but that the physico-chemical laws are the same in all nature.

Subsequently the sciences of animal behavior and psychology came into being, and showed that mind, too, was a proper subject for science—with what results I shall attempt to show later.

For the present let us confine ourselves to biology. What

of ourselves does she show us in her glass? She dethrones man from an old throne, to seat him on a new. Before Copernicus, Kepler, and Galileo, our earth was the centre of the universe—or was, for us, the centre; they, and later astronomers, have made it nothing but a minor planet of a minor star in one out of a myriad cosmic systems. But man continued central. What matter if earth were but a planet? Man was still the objective of creation, the meaning of the scheme. Right up to the middle of the last century, the most eminent men of science could and did continue to discuss the properties of matter, the nature of the earth, and its animal and plant inhabitants solely from the standpoint of their utility to this egotistic human demigod.

From this self-erected pedestal he was cast down by Lyell and Darwin. They threw their searchlight into the dark places, and it was at once seen that neither the earth nor its animals and plants had been created to serve and minister to man. The oak or the vine, the dog or the horse, existed because they were fit to exist, because capable of survival; the life of each living thing was centred, though unconsciously, upon its own ends only, and the capacity to live was sufficient and sole justification for its presence on earth. Not merely this, but more: not only were they not created with human needs in view, but man came into being in a certain real sense with reference to them.

He, like all other living things, must be adapted to the world he lives in. This means that his attributes, both physical and mental, have been, and are, continually being molded to fit the world in which he lives. Thus, far from the world having been deliberately shaped to go with the character of the star actor, this actor himself owes his very nature and his part in the play to the pressure of the world and the ages of its slow, blind molding. Not only that,

but if evolution is the fact it so indubitably proclaims itself, then there is no reason to suppose that the evolutionary process has reached its limit in man—he is an unfinished as well as a one-sided being.

Here we have the principle which may be called biological relativity. Man's nature, like that of all other organisms, can be understood only in relation to the rest of his world, living and not-living; if that had been different, he would have been different. If there had been no beasts of prey, his sense of fear would have never developed as it actually did; if X-rays were not absent in nature, but had been passing through our atmosphere abundantly like light, he would have possessed sense-organs to detect them, and a skin to keep them from penetration; if sugar were poisonous, and yet as common in nature as it actually is, we should be so constructed as to find sweetness profoundly disagreeable. Bergson took the most far-reaching step in this direction when he pointed out that the very methods of our intellect, the particular ways in which our reason works, appear to have been developed in relation to the material necessities of life, to the need for controlling the behavior of separate material objects. The intuitional side of thought has had relatively little survival value in the critical early evolution of man, and remains to this day under-developed.

Meanwhile comparative psychology, studying the behavior and mind of animals, shows the line along which mental evolution has progressed. Retentiveness of memory, readiness of associations, efficiency and variety of sense-organs (the entrance channels of all knowledge), intensity of feeling and of will—all these, starting from the mechanical uniformity of response and narrowness of knowledge seen in the lowest organisms, have gradually increased. Recent work has especially emphasized one point: that

higher animals are enabled to comprehend and act intelligently when faced with situations which are too complex for lower animals. Stand in an enclosure of wire netting with the door open behind you and throw some food over the wire. If you have a dog with you, it will, after a few ineffectual attempts to get through the wire, grasp the situation and make off through the door and round. A child of eight would have gone straight round; but the average barndoor fowl will never grasp the situation as a whole, and continues to make ineffectual efforts to get through until it is tired.

What is there to prevent the evolution of a brain and mind as much more capable than ours of complex grasp as is ours than a hen's? Already in men of genius we see adumbrations of such power. Mozart, in some way as unconveyable by words to lesser minds as is sight to a blind man, tells us that he could experience the whole of one of his symphonies in one instant of time; great mathematicians often see the answer to a problem in a flash, and then have to spend days in verifying it step by step; the great mystic gathers all his knowledge and all his feeling in a point of aspiration and contemplation, and enjoys an experience unknown to smaller minds.

Man thus becomes a product of the evolutionary mill like any other. Like the snail or the pine-tree, the tiger or the duckweed, he exists, and existence is his justification no more and no less than it is theirs. He might have been stronger, with more avenues of knowledge, or incapable of fear or anger, or endowed with a comprehension beyond that of genius; he is, in actuality, a product of his environment, and a product at a definite and not necessarily very high level of development.

And so he has been turned out of that throne. But there

is another, in which we may justly install him. The study of the actual course of evolution, as revealed in fossils, in embryos, in comparative anatomy, shows clearly enough that evolutionary change has not been completely at random, but that it has a chief direction. Through the millions of years during which life has existed on this planet, there has been an increase in certain properties of life, or, more accurately, in their maximum level. These properties are size (up to a certain limit), efficiency, complexity, harmony of parts; and on the mental side memory, power of learning, greater intensity of emotion and of will. You can sum them up under the still more general heads of greater independence, greater control, greater intensity of mental process. This increase has not been universal. Some types appear to have remained stationary, others to branch out all on the same level, others to specialize up blind alleys of complexity, others to degenerate into sedentary sloth or shapeless parasitism. But the maximum level of the qualities I have mentioned goes on increasing from epoch to epoch. The direction may appear to be reversed, the whole scheme of progress overturned, as when the marvellous great beasts of the age of reptiles were extinguished and their places taken by the early mammals, smaller and less powerful. Yet the whole mammalian plan was more advanced than the reptilian, and the temporary reverse was a necessary preface to further advance—advance which would have been impossible but for two new characters brought in by mammals, warm blood and the nourishment of the young by the mother, pre-natally in the womb, later by the mother's milk.

In spite of degeneration and temporary reversal, the advance at the highest level was continued; and it is this

evolutionary direction which we may, I think justly, call biological progress.

What is our justification? The fact that there is a direction in evolution is remarkable enough. But progress is more than direction, it is movement in the *right* direction. And we are legitimately using the word progress here, since the direction in which pre-human evolution on the whole has moved in the past is the same as that which is in our human minds when we speak of progress.

If then we look again at man in the light of this new idea of evolutionary progress, we find more reason for congratulation. Man may be a mere spurt thrown out by evolving life in its blind course, he may be only a step towards as yet undreamed-of possibilities—but whatever he be, he has one actual and tangible claim: he is the highest organism yet evolved; he stands at the present pinnacle of evolutionary progress, and his own ideas and ideals are pointing him to a path which continues in the same direction as was followed by that progress in the past.

On the other hand, if a tapeworm could discover and reflect as man does, it could not derive the same satisfaction from a knowledge of evolution. If, also, it could keep the fair-mindedness of pure reason, it would have to admit that the path which its ancestors had trodden, the gradual adaptation to a parasitic life, the loss of limbs, of eyes and ears, of digestive organs, the narrow specialization which fits it to one and only one home, one particular part of the bowels of one particular animal—it would have to admit that the direction of its evolution was definitely the reverse of that of the chief trend of life. Life was continually producing new combinations, new levels of existence were continually coming into being, and the novelty was

predominantly in one direction; but the tapeworm's movement was definitely away from this.

Even a beautifully specialized creature like a deer, a bird, or a lion would (again if it could reason!) be compelled to admit that it, too, was out of the main line. It would find that intense adaptation in one direction, at the expense of other directions, had invariably meant surrendering the possibility of advance to a new level of biological progress. Over-specialization, however beautiful and in their way perfect its results, leaves the organism, whether plant, animal, or man, in a cul-de-sac.

Thus man, in asserting biological progress and himself at the head and front of it, is not merely projecting his own ways, his own work and wishes and hopes into biology, but is finding that his wishes and ways of working are but part of something far greater than himself, which *was* æons before he ever came to the birth, and *will be* æons after he has given birth, like Chronos, to his own successor and destroyer. He and his hopes do not stand isolated, a feeble candle flickering with pathetic bravado in the midst of an appalling and alien universe, but are the culmination and condensation of a long age of travail that has gone before. Here biology becomes of profound importance to religion, for here it gives to man firm ground for his faith and tangible assurance that the belief which is in him is not vain, not mere delusion. This will be a corner-stone of any theology which attempts to take account of science.

Now let us return to the point where we left the two streams of scientific and religious development and started on our excursus into biology. Let us look at the matter from a somewhat different angle.

In the Middle Ages, European civilization had a single underlying theory of existence. It found room for all

aspects of the world, philosophical, scientific, devotional, and practical, within this one scheme; and this scheme was a particular elaboration of monotheism.

Any such universal scheme must take account of all sides of man's experience. This scheme accounted for external nature and its operations as the creation of an absolute and personal God; it satisfied man's metaphysical needs with the scholastic philosophy; it accounted for those facts and events of the human spirit which in theological terminology we call the sense of sin, conversion, the sense of grace, mystical experience, inspiration, possession, by reference to the Christian scheme of theology. The sense of sin depended on the fact of original sin, and that on the fall of man; conversion and grace were possible only as the result of the incarnation; mystical experience was a direct communion with a personal God; inspiration was a true inspiration by divine beings; possession the result of the activities of devils. The instinctive demand for justice which man feels in a world in which fairness seems often so conspicuously absent was satisfied by a system of rewards and punishments in another life. Plagues, earthquakes and other natural catastrophes were ascribed to the anger of God; the sense of the incompleteness and futility of this life, the desire for existence as such, and the inevitable longing that the partings brought about by death should not be eternal were met by the doctrine of personal immortality. The necessity which the average man feels for authoritative guidance was embodied in the Church, which claimed to be the sole true interpreter of the voice of God; the spirit of sacrifice was also catered for within the scheme by the establishment of the various religious orders; and the contrast between the violent world of secular life and the beliefs of the church could be bridged in practice by the doctrine of salvation by

faith, which made a holy death of more importance than a lawless life. In fine, every activity of man could find its place within this vast, dominant and coherent scheme, and the original basis of the scheme was the existence of a single omnipotent, personal God. This was assumed unquestioningly as the first foundation on which all the rest of the edifice was subsequently reared. It was the major premiss of the whole argument; the minor premiss was found in the nature of things as the men of that time saw and understood them; from these premisses conclusion upon conclusion directly and logically flowed.

Since that time, the advance of thought, philosophical, moral, and scientific, has necessitated a gradual but steady revision of this position. Never since the Reformation has there been that same triumphantly single and embracing outlook underlying all Western civilization.

I have not the space for detail. Everyone knows that the original Western church has split into dozens of churches, that new religions have sprung up, that free thought has gradually, in the face of persecution, won for itself the right to exist, and that an increasing number of thinking men and women are finding it impossible to adhere to any church. In every European country there are great bodies of people who are cramped and hindered either in their intellectual or their religious life or both because of the conflict between orthodox science and orthodox religion. Some gain peace of mind by shutting their eyes to the facts of science. That was the case of the great scholastic philosopher Cremonini, who, after one look through Galileo's telescope at Jupiter and his satellites, said that he would never look through it again, as it was contrary to Aristotle; so, too, of an old lady in Western America of whom a biological friend recently told me. At a scientific soirée in the local college,

one of the exhibits was a living cell under the microscope; the old lady looked, drew back, shook her head, and said: "No, Professor Smith, you may look at such things, but I prefer to stay by my Bible."

Others, accepting the commonplace view of science, can only rationalize their state of mind and lead a self-consistent life by belittling all religion. Some, like Voltaire, brand the whole of it as imposture. Others regard it as a primitive survival, or as the mere outcome of superstition; still others, as a beautiful figment of the imagination; they envy believers its enjoyment, but find that, alas, it is not for them.

Some, like Jung the psychologist, have the hardihood to say that while they personally believe religion to be only the false rationalization of primitive thought and superstition, yet they also believe that it is necessary for the bulk of humanity, and therefore encourage its practice. Such a position appears, I must confess, as a denial of any rationality or coherence in the universe, and is in the long run a counsel of despair. There are still others who try to ride two horses at once—and find that this method of locomotion is neither comfortable nor very practical. But there are many who believe in the general reasonableness of things, and to them it is certain that there must be a way out of the deadlock. It may be that it is in the long run our own reason which, so to speak, gets into phenomena—but even if this extreme view were true, our reason none the less *is* reason, and is itself a product of the order of things which it is making reasonable. To them it will seem that the time has come to examine our premisses again, and to see if a fresh start would not make it possible to reconcile the apparently irreconcilable.

The mediæval conception of the universe and man's

relation to it was based upon a theological premiss. The greatest single difference between the Middle Ages and to-day has been the rise of the scientific or naturalistic spirit, the investigation of nature as she is, in the search for the truth of phenomena, without prejudice and in the confidence that truth is the first pre-requisite for mind's right living. Should we not be justified in seeing what would happen if we took the scientific standpoint as our basis, and started on the construction of our philosophy of life from a naturalistic premiss?

What does such a premiss imply? It implies, first, that our philosophy and view of the world must be a deduction from observed facts, and that supernatural and unprovable explanations are inadmissible when natural and scientific ones are available. It must refuse to accept any theory or belief, however desirable it may seem, unless it be brought into some kind of harmony with the rest of our knowledge. It must accept the unity, the orderliness of nature, its coherence and its congruity with itself. It must "accept the universe" and not seek to live in the imagination.

What then are the bases for our naturalism? First we have the inorganic world, made intelligible to us by physics and chemistry: one matter and one energy without end. Out of the independent electrons are organized structures of a higher order, the atoms; atoms join up to inorganic molecules; and finally (so it appears is the only way in which we can fill the gaps in our knowledge of the past), from more complicated carbon-containing molecules was generated living matter. The original world-stuff thus became progressively organized on higher and higher levels of complexity, becoming capable at each level of new performances, acquiring new properties. Even the evolution of dead matter is creative in Bergson's sense. Living matter then takes

up the story, and, as we have seen, becomes organized in more and more complex and efficient forms, culminating along different lines in the ant and the bee, the giant cuttlefish, the bird, and the mammal; and the mammal takes the highest step so far taken, to culminate in man.

Consciousness *appears,* as we usually say, in higher animals. As we have seen, the easiest way to look at this problem is to think of this not as a wholly new appearance, but as an intensification of processes at work from the beginning, which were not detectible before because their intensity was too low for us to detect their effect. What is probably a real parallel is seen in the electrical properties of matter. All changes in matter, dead or alive, are accompanied by electrical change. Every time one of our muscles contracts or glands secretes, there is a minute electric discharge —but so small that it can only be detected by very delicate apparatus. But in the electric eel and a few other fish certain muscles have been charged in such a way that they can administer a really powerful electric shock. It is probably in a parallel way that we must look at the brain—as an intensifier, an organ which makes it possible for mental processes, or at least processes of the same essential nature as those which we call mental, to become intensified. Doubtless such essentially mental processes accompany all activity of dead and living matter—but at such a low intensity that they are not detected, and remain mere accidental by-products. But finally in the brain the generation of intense mental processes becomes one of the main functions of the organ; and their presence becomes of the greatest biological value to their possessor.

That is to say, our naturalistic philosophy must be monistic—it must not assert duality of matter and spirit as fundamental, but must believe in their unity as different

aspects of a something more fundamental and more single.

Professor Matthews, one of your leading biochemists, has recently voiced the same idea, which implies at the start that the purely materialist view of things is wholly false, since it leaves out of account the most essential aspect of the reality we know.

We see further, as I pointed out before, that there is a main direction in evolution, a biological progress, and that in man this progress finds its present summit.

The change from prehuman to human is comparable in its evolutionary importance to the change from not-life to life, or from the electronic to the atomic level of matter. It involves the attainment of a new level of complexity. Through this change, the world-stuff acquired new properties, new possibilities of performance. The precise method by which the change was brought about does not particularly matter to us. There can, however, be no doubt in the mind of any one who has considered the evidence, that modern man sprang from more beast-like prehistoric types; they in their turn from an organism which, though certainly not one of the existing anthropoid apes, was of a general ape-like character; this again from a type which would be classified among the old-world tailed monkeys, this from a lemur-like animal, and this from some small and primitive type of insectivorous mammal.

However, especially in this democratic age, more importance is attached to a man's performance than to his origins; and it is the results of the change which alone are of special interest to us in our present quest.

The new level on which man emerged when he ceased to be brute was characterized by the power of tool-making, of speech, of the power of framing concepts, of making use of rational thought, and, therefore, of self-conscious-

ness. Out of these original properties are automatically generated the further properties which characterize man as man. Other properties, such as gregarious instinct, maternal love, the erect posture, and so forth, are found in other creatures as well.

One of the direct consequences of the step was the creation of a set of conscious values. Animals can pursue one end in preference to another, but they apparently are incapable of framing a set of conscious values with reference to these ends. What is more, what we may call the unconscious values of the animal are supplemented in man by a whole new crop of conscious values of a different character. Through his power of framing concepts and thinking logically, man can construct so-called absolute values. Men can understand what is meant by abstract ideas such as truth, justice, love, beauty, and will regulate their lives by them.

As reason and good-will work on the problem of existence, values change, and often ideas that once seemed incompatible are later found to be mutually helpful. This is one of the greatest difficulties in the intercourse between different nations, classes, sects, and individuals—in part that the various parties have a different scale of values, in part that their values are on different levels. When this last is the case, intelligent and full intercourse is impossible—the two parties are really speaking different languages.

As further results of the change, new activities and new kinds of behavior, previously unknown in evolutionary history, are brought into being. Only among mankind, not among dogs, birds, or ants, do we find science, literature, religion, art, laws, political activity. Now, this is where many materialistically-inclined minds appear to go astray. They are willing enough to analyse those parts of human activity which allow of such analysis into a set of chemical

and physical processes; but when they are confronted with phenomena *not* analysable into physics and chemistry, they simply ignore them or attempt to explain them away. But these, just as much as the others, are phenomena. They are all part of the single reality of nature. While science was still preëminently chemical and physical science, such an attitude was more or less natural; but the rise of biology and psychology makes the position futile. The materialistic science of the latter half of the past century could be materialistic only because it was incomplete. The science of to-day must be monistic, and take the mental as well as the material properties of the world-stuff into consideration.

Science must attempt to explain the existence of scientific enquiry itself; among the raw materials of which it must take account are facts such as that men are willing to die for an idea, or to devote their lives to the pursuit of beauty. The almost universal existence of religion, in one form or another among men, is equally a fact of science with the fact that water is made of molecules each consisting of two atoms of hydrogen and one of oxygen, or that the stomach secretes a digestive juice. Our new premiss thus rejects supernaturalism and demands a naturalistic attitude towards religion.

That being so, science asks, "What then *is* religion in practice?" It examines all the religions of humanity, savage, barbaric, and civilized, and orders its results. And so we have a new branch of science—the Comparative History of Religion.

What have we gained by such a study? Some of it we have briefly touched on in the early part of this lecture. Looked at from our present standpoint, the most important fact which emerges from it is the universal or almost universal existence of a religious sentiment, or, as it is often inaccur-

ately called, a religious sense or instinct, in humanity. Viewing man biologically, as would the proverbial Martian scientist, we thus find that one of his characteristic activities is religion, in the same way as is hive-building to a bee, or contraction to a muscle. This, of course, tells us nothing of the desirability, or otherwise, of religion.

We have, however, not yet asked ourselves the question, what religion *is*, in what its essence consists. To many, the idea of a personal God is taken as being an essential part of any and every religion. Even such a capable thinker as Martineau fell into this error. Somehow or other he and others who have the same idea manage to forget the fact that Buddhism, one of the three great historic religions of the world, is in its true form (still practiced by very large numbers of people) completely atheistic. It neither denies nor affirms a god; it manages to exist and to satisfy the religious craving of its devotees without one.

The study of primitive religion has further revealed a whole level of religious thought in which no conception of God or gods existed, but where, since no clear demarcation seems to have been made between self and not-self, there was a fine confused theory of existence in which inanimate forces and human personality, matter and spirit, imagination and reality, wishes and facts were all inextricably interwoven, giving us the fetichism, animism and magic of the earliest religions.

Many and various other definitions of religion have been given. After thinking over a number of them, I tried to frame one myself, which I shall venture to quote to you because no less a personage than Dean Inge held it up as one of the best he knew. "Religion," I wrote, "religion, itself, is the reaction between man as a personality on the one side, and, on the other, all of the universe with which

he comes into contact." And I still feel that that embraces most of the facts of religion, without being too broad to admit other activities within its bounds.

Further, we can trace a higher and a lower in religion, a progress in its evolution as in other evolution. Undoubtedly, monotheism represents an advance on polytheism or fetichism; undoubtedly, the highest forms of Christianity have rid themselves of superstitions, fears, and barbaric rituals with which earlier religions have been encumbered. Undoubtedly, too, the ideas embodied in the orthodox beliefs of Christianity represent (if I may use the word *represent* in a rather special sense), the realities of actual experience very closely and often very wonderfully.

But (and you will now see why I use the word *represent*), a representation may be of various kinds. It may, for instance, be realistic like a photograph; or it may be highly symbolic, like many works of art and literature.

It is my personal belief, which I put before you for what it is worth, that the representation of religious reality given by orthodox Christianity is in many important respects only symbolic, and that that is the reason why it conflicts with modern knowledge.

In religious practice and experience the Christian churches (or some of them) are more advanced than any others. The facts of the religious life to which Christianity devotes special attention are the highest and most essential facts. The sense of sin and of atonement; communion; the fruits of meditation; the experience of conversion and of grace; the value of humility, self-sacrifice and love; the hunger and thirst after righteousness; the desire for a unified and coherent explanation of the universe in which we find ourselves—these, and many others which I could mention, are

facts of reality which must be taken into account, and taken into account especially by religion.

But the particular way in which they are accounted for, the particular forms which they are given by Christianity—these need not necessarily have more than symbolic value. That is already a great value. But we must be careful not to let the symbolism come into open conflict with hard fact—which it can only do when it believes itself also to be hard fact.

In my belief, the fundamental symbolization of Christianity is the symbolization of the forces acting in the universe as a personal, omnipotent, divine being. It is this one interpretation of reality that provides the premiss for that whole set of conclusions which are the bone of contention between Christianity and Science to-day.

If we proceed dispassionately, and in the same scientific spirit with which we analyse other phenomena, to analyse the idea of God as actually held by men of various religions at various times in the world's history, it is possible to find out what minimum and what maximum of meaning attaches to the idea of God in this, we may say, anthropological usage of the term. Let me read what I have written elsewhere on this subject.[1]

> We may either call the sum of the forces acting in the cosmos the manifestations of God, who in this case must be the Absolute God, and unknowable except through these manifestations, or we may confine the term God to its anthropological usage, as denoting the actual objects of human religion, in which case we must admit that the term God as understood by man is constituted by *man's idea* of the forces acting in the cosmos, so that not only are these forces involved, not only a possible Absolute God behind them, but also the organizing power of the human mind.
>
> I wish you here to agree to my adopting the second alternative. . . . We can therefore now say that God is one, but

[1] "Essays of a Biologist," London, 1923, pp. 262-265, 283-284.

that though one, has several aspects. There is one aspect of God which is neutral to us, in a way hostile, mere Power operating in the vastness of the stellar universes, apprehended only as orderly, tending in a direction which appears to be in the long run inimical. . . . There is another aspect, which is the one seen operating in that sphere which comprises the whole of life upon this earth. . . . This aspect of God is our refuge and guarantee, for here we find our assurance that our human life is a part of a whole that is not antagonistic, but moves in the same general direction as do our history and our aims. There does exist, in Matthew Arnold's phrase, "a power, not ourselves, that makes for righteousness." And this second aspect is not wholly separate from the first, . . . for the first is its parent, physically and temporally, and the direction of biological progress is the continuation of a line of development marked out, within the opposed inorganic direction, even from the first.

Next, there is . . . the third aspect of God, which enshrines the directive forces operating in man. These directive forces are our instincts, our needs, our values, our ideals. When those are harmonized with each other and with the outer world by reason and experience, they form a power which we can see has been directive, normative in the past, and will continue to be so in the future. . . . Although in a sense this aspect is the smallest, as comprising the smallest physical field, yet in another it is the largest, since man's ideals are in themselves unlimited, non-finite. . . . This third aspect is again historically the offspring of the second, and through the second of the first. . . .

God in this sense is the universe, not as such, but so far as grasped as a whole by a mind, embodied in an idea, and in consequence capable of influencing that mind, and through it the whole course of events. . . . There exists no other meaning of the term which, on analysis, is found to convey anything scientific or comprehensible to us. We may reason that there is an Absolute [Personal] God behind the universe and our idea of it. But we have no proof of this statement, and such an Absolute God is, as Spencer pointed out, an Unknowable, and accordingly no concern of ours. That part and those aspects of the universe which have been grasped by us are proving to contain the key to many of our difficulties; meanwhile we can only be humble and admit that our idea of God, even in this restricted sense, is still extremely incomplete: and in this sense there is a God far greater than our present idea and knowledge of God, only waiting to be discovered. . . .

> By organizing our knowledge of outer reality after the pattern of a personality, we make it possible for it to interpenetrate our private personality. If, therefore, we have, in any true sense of the word, "found religion," it means that we shall have so organized our minds that, for flashes at least, we attain to a sense of interpenetration with the reality around us—that reality which includes not only the celestial bodies, the rocks and waters, not only evolving life, but also other human beings, also ideas, also ideals.
>
> This, to my mind, is what actually happens when men speak of communion with God. It is a setting, an organizing of our experiences of the universe in relation with the driving forces of our soul or mental being, so that the two are united and harmonized. There is a resolution of conflicts, an attainment of profound serenity, a conviction that the experience is of the utmost value and importance.
>
> . . . Here we see religion in operation. It is a relating of the personality as a unit to external reality as a unit—and in a relation of harmony. First the inner structure of the mind must be organized into a harmonious unit, then our knowledge of external reality organized similarly, and finally, in religious experience, the two must be harmonized in interpenetrating union.

That is to say, it is possible to say that the term God is a term denoting the sum of the forces of the cosmos as perceived by and acting upon mind, and symbolized as a personality.

That this statement of the case should be possible and even coherent does not imply that it is true. The reality is often far more complex and far more wonderful than our human approximations. I merely speak of it as a solution, which, at my present stage of intellectual development, satisfies me and has helped me to bridge the rift between science and religion which for many years appeared unbridgeable.

In any event, what I am firmly convinced of is that the naturalistic view of religion, which has been made possible only by evolutionary biology and psychology, is right in its fundamental tenet. It assures us that religion is a natural and high function of the human mind, not something de-

pendent only on authority, or on revelation, or on ritual or propitiatory sacrifice.

I spoke in my previous lecture of health as an art like other kinds of living. Religion, too, is an art, which must be practiced vitally if it is to have the fullest meaning and value.

Too many men and women, though passively accepting the orthodox formulations of their church's creed, are still really in the magic stage as regards their religious practice. They regard religion as alchemy regarded the philosopher's stone, as something external to them, which you can obtain, and with which once obtained you can perform all sorts of miraculous tricks, such as attaining salvation at one bound, or being entitled to look down on believers in any other creeds as heathen or heretics.

Such ideas are the ideas of a savage or of an undisciplined mind which has not reached a higher level of thinking than the savage. Precisely as with health, or with love, or with the scientific spirit, religion is an active internal principle, a natural function of the living man—or it is nothing. I will read you, if I may, a couple of quotations. The first is from the pen of Söderblöm, the Archbishop of Upsala. He speaks of a certain attitude of mind towards purely intellectual negative criticism, and says: "I feel it . . . most markedly in strong young intelligences in Germany which are passing through the ordeal of starvation and humiliation. They say: 'Thanks, we have had enough of modernism. It was a helpful drug to a previous generation, agonizing under the pressure of tyrannical formulas and a Bible-worship lacking the historic view. But now we have had enough of it. We have the great epoch of historic research in Holy Writ and religions behind us. It is most interesting to know more and more of the relativities of

history in their interdependence. But our hungering soul cannot feed on them. Modernists sometimes forget that the walls, not the windows, make the building. Where in the moving phenomena of religious evolution is the rock, the Truth?' An eminent young German theologian has called that tendency: *das Heimweh nach dem Unbedingten,* the nostalgia after the unconditioned. I am persuaded that metaphysics and systematic construction will occupy in the next generation of religious research the same dominating place that historical investigation has had in our times." [1]

In fact he implies that future work will be chiefly devoted to a search for the underlying basis of religious experience, and a definite attempt at new positive construction on that foundation.

Let me read you a quotation from that sane and sage spirit, Havelock Ellis [2]:

> "How is Religion still possible?" This question is posed by so able a thinker as Dr. Merz as the question of paramount importance, and he can find only a paradoxical answer.
>
> It is a question which still seems to be taken seriously by many otherwise intelligent persons who are thereby stranded in the end on all sorts of hidden sandbanks. They do not ask: How is Walking still possible? They do not ask: How is Hunger still possible? Yet it is really the same kind of question.
>
> It is always marvelous to find how people worry themselves over unnecessary problems and spin the most fantastic webs of abstruse speculation around even the simplest things. Religion, if it is anything at all, must be a natural organic function, like walking, like eating, better still, one may say, like loving. For the closest analogy, and indeed real relationship, of religion, is with the function of reproduction and the emotions of sex. The functions of walking and eating are more or less necessary to life in their rhythmic recurrence, and it is legitimate in their absence to endeavor to stimulate them into action. But the function of religion, like that of love, is not

[1] The Forum, 1924, p. 334.
[2] *Ibid.*, pp. 324-5.

necessary to life, nor may it with any certainty be stimulated into activity. Need it? These functions are either working within you or they are not. If not, then it is clear that your organism is in no need of them at the present moment, and perhaps is born without the aptitude to experience them. And if so, there are those who will tell you that you represent a superior type of humanity. Therefore whether if not so, or whether so, why worry?

I do not, indeed, myself think that the inaptitude for the function of religion—ancient as the religious emotions are,—represents a higher stage of development. But I am sure that either the function is there or it is not there, and that no intellectual speculations will take its place or hasten its manifestation. Religion, like love, develops and harmonizes our rarest and most extravagant emotions. It exalts us above the commonplace routine of our daily life, and it makes us supreme over the world. But, like love also, it is a little ridiculous to those who are unable to experience it. And since they can survive quite well without experiencing it, let them be thankful, as we also are thankful.

If we are conditioned beings, produced by an evolution which has always been related to the world around, one-sided, unfinished—and this is the humility which biology enjoins—we cannot afford to be intolerant, for such presumption becomes ridiculous.

Furthermore, our toleration must not be merely passive, a tired intellectual gesture; it must be active, springing from the belief and knowledge that truth is too large to be revealed in but one form, or one creed, or one way of life.

We must really accept the hard saying that out of diversity alone comes advance, and that any one human mind is too small to grasp more than a little truth, to live more than a little reality.

Listen to one more quotation from Havelock Ellis: "The diversity of the world, therefore, is natural. Yet not less natural is this inability to accept its own diversity. It is by limitation,—the limitation which all art involves,—that Nature becomes diverse, fantastic, seemingly artificial. It

is by that same limitation that these diverse forms cannot accept each other. I recall the critical, disdainful gaze of a small terrier as he stood still to watch a great goose pass by. Let us, therefore, accept with joy the diversity of the world, and with equal joy its inability to accept its own diversity. For that also is delightful." [1]

I must close, and I will do so by affirming another belief which I hold tenaciously. It is that only by having some ground-work of common belief, will it be possible for humanity to set out with a happy prospect of success upon the problems which press on it from every side. There is, at present, not only a conflict between the beliefs of orthodox science and orthodox religion, but also between those of nationalism and internationalism, and of materialism and idealism. Yet a common underlying basis would help solve all the antitheses.

It is possible for such a common basis to be attained: it is only possible for it to be attained by utilizing every source of knowledge and feeling: and it will, I believe, be found that biology has made some of the most important contributions on the intellectual side towards the construction of such a basis.

JULIAN S. HUXLEY.

[1] *Ibid.*, p. 326.

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